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S. AUDO

DEVELOPMENT OF A DYNAMIC MODEL FOR STRATEGIC PORT PLANNING AND INVESTMENT

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SUMMARY

Different levels of congestion are encountered in ports all over the world and particularly in developing countries. Depending on the volume of traffic flow over time, the changes of development in the economy and industrial activity and the random arrival and service pattern of ships; the optimum berthing capacity resulting in minimum cost at any future time period has to be determined to avoid undesirable repercussions.

The existing methods fail to provide the links between the aggregate economy, demand and optimal berthing capacity for all time periods of the planning horizon, and conventional techniques based on static frameworks are used to arrive at optimal strategies for specific times into the future.

This study is an attempt to remedy those difficulties and relate future demand to optimal berthing capacity in an interactive dynamic fashion.

Three models are developed: a forecasting model linking seaborne trade to gross domestic product, population, production, consumption and elasticity of demand; a simulation model relating the various demand levels to different port configurations; and an investment model relating the resulting congestion cost to capital cost, where an optimal strategy in berthing capacity is achieved for the years 1985, 1990, 1995 and 2000.

The last model has been extended using the above mentioned points in time to result in an optimal berthing capacity for any future time period within the planning horizon 1985 - 2000. This model is validated through forecasting, simulating and appraising the 1992 and 1998 results and reducing the amount, cost, and time of work by 75 per cent.

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CONTENTS | PAGE NO.

LIST OF APPENDICES — PAGE NO.

CHAPTER 1

GENERAL CONTEXT: PORT PLANNING AND RELATED RESEARCH

1.1 Port Planning and Development

Transport in its different modes is the artery of economic growth, development and progress which is vital for the flow of national and international trade. It accounts for between 10 and 20 percent of the gross domestic product of most industrial nations (Imakita 1978) and much more in the less developed countries with rich natural resources that are developing very fast. The faster the economy grows, the greater the demand for more efficient transport systems linking less developed areas which have ample resources with other areas where resources are needed for manufacturing industrial goods which in turn have to be moved to wherever they are demanded and consumed.

In Iraq where over 90 percent of trade (imports and exports) is carried by maritime transport, the ports constitute the most essential and sensitive part of the transport system. Any inadequacy of a nation's ports will depress the level of throughput and result in long queues with cargo being laid up in expensive ships instead of cheaper stores.

The consequences of failure to provide proper port capacity before the increased traffic arrives are clearly illustrated by the recent congestion in many ports of the world, in particular in developing countries. Perhaps the most remarkable case of heavy congestion ever faced by any country was that which began to build up in Nigeria in 1974. The (Observer) reported that "More than 400 ships, 240 of them carrying cement are stuck outside Lagos harbour. Most have little hope of unloading their cargo for up to two years ..... the oil-rich Nigerian Government is forced to pay an average of £1,225 a day in waiting time". The outstanding reason being that orders for 16 million tons of cement were made by the Nigerian Government when the actual handling rate of the only available port was estimated at 1.3 million tons a year. It is also reported that surcharges resulting from port congestion cost Iran some one billion dollars during the financial year April 1975 to

March 1976.

The enormous sums of money lost through congestion would often have been more than sufficient to build a system of modern ports. Seaports can, moreover, play a major role in promoting international trade by generating commercial and industrial activities which directly assist the economic progress of the country. The history of many European ports - for example, Hamburg, Antwerp, Marseilles and Rotterdam - shows how a bold policy of extending and modernising ports can revitalise the economy of the region (UNCTAD 1978).

At a conference by UNCTAD in Geneva (Hinterland Bimonthly review 1977), it was established that the average number of days a ship must wait for a berth in thirty ports which are regularly subject to congestion has grown as follows:

Year	Days
1971	2.2
1972	2,3
1973	4,0
1974	4,8
1975	14,3
1976	40,5

These figures refer exclusively to general cargo vessels. The waiting period for bulk carriers in the same ports was often much longer.

There is no doubt that congestion produces serious repercussions of all sorts. Ships and cargo will be tied up for fairly long periods thus freezing capital as well as goods for nothing and may result in substantial diversion of traffic in the long run. This will result in raising the cost of goods and might even lead to shortages, eventually resulting in delays in the implementation of projects. The main reason for congestion is the big import surge which has become commonplace in most of the Middle Eastern countries.

Professor Leontief (Maritime Traffic and World Ports 1979) estimated in that port traffic for the Middle East will grow by twenty eight-fold for general cargo and by more than ten-fold for dry bulk by the end of this century.

The seven berths of Damman, before the big import boom beginning in 1973, handled 1,308,878 tons. By 1975 Damman had added another six berths and an increase in the number of berths to forty-two by 1980 was planned (The Sunday Times). If that target is met, it will mean an increase in tonnage capacity by more than 300 percent in five years.

What has been said above illustrates clearly how important it is for any country to determine as early as possible the right level of capacity required to meet present and future demands in order to avoid congestion. Surprisingly this transport sector seems to have received a relatively small amount of attention among researchers, at least until recently. Following upon a surge of imports in very large proportions into the Middle Eastern countries - raw materials, industrial goods, entire plants and so on - attention has inevitably been drawn more and more to this field, and especially to port planning and development as the most important aspect of this phenomenon.

Too often port planning is seen as a technical engineering problem arising from a sudden lack of capacity. However, one aim of this research is to place port planning within the context of long term national economic planning and to see it as a strategic planning activity, rather than an engineering solution to a short term technical problem. In a strategic planning context, it is necessary to relate port requirements to forecasts of national growth, and to consider a range of possible growth paths and with an analysis of the consequences of alternative levels of port investment. With these investment possibilities phased over time.

Port planning problems depend on the varying volume of traffic flow over time and the changes of the development in the economy and industrial activity. If seaborne trade is increasing with time then one of the most important means by which improvement in ports is achieved is through new investment allowing for increased physical capacity.

Changing the physical capacity of the port to meet present and future requirements is a dynamic process. The optimum for the dynamic process (that is, providing the best form of expansion in the course of time) is attained by balancing the gains from reducing congestion against the costs of doing so. Therefore, this study will not consider in any detail the day-to-day requirements of operating the port, such as the number of tugs, pilots, forklift trucks .... etc., but concentrates mainly on the timing and level of investment for the berths of the commercial ports.

1.2 Overview of the Methods Used in Port Planning

Since port planning problems are essentially queueing problems because of the stochastic nature of the arrival and service times of ships, most of the literature in this field makes intensive use of queueing theory. Others have based their studies on simulation of particular ports or parts of a port, thus gaining more insight into the problem and tackling it in a more realistic way since ports all over the world vary in their operating policies, differ in their features, characteristics and types of cargo and ships they handle.

The majority of the work published appears to be a descriptive summary of what was done and what was obtained in a particular port or terminal, without details of the methods employed. Unfortunately the literature in this field suffers certain limitations in forecasting seaborne trade; queueing theory and simulation; and investment appraisal which are discussed below.

Trade forecasts and their link to the economy and economic growth are ignored in almost all the studies and are assumed to be given or made available by the country concerned or by different consulting firms, and whenever taken into consideration, the cargo tonnage which is dynamically changing at the port was obtained by numerical computations. If such a method is used, enormous computations on trial and error basis are required to examine whether the condition of the total cargo tonnage is satisfied or not (Noritake and Kimaru 1983).

In all the papers discussed in section 1.3 of this study seaborne projections are assumed to be known, except in the case of Bergen (Institute of Transport Economy 1973) where they mention that the forecasting process was started by a discussion of the development of the import and export to Norway and comparisons with growth in the Gross National Product were made. The background figures were worked out by a team under the Ministry of Finance, analysing the future economic development in Norway and the forecasts were worked out by using a comprehensive economic growth model for the national economy. While foreign trade data were taken from a customs statistics already punched on cards, investigations to estimate domestic trade were carried out by the Norwegian Central Bureau of Statistics and the yearly figures for the Bergen Port Authority which indicated that a conservative and radical yearly increase of zero and 3 percent respectively would be reasonable estimates.

The most commonly adopted techniques used in forecasting seaborne demand are discussed briefly below (detailed analysis of these techniques is provided in section 4.2 of chapter 4).

The simplest technique used is trend extrapolation where forecasts are usually based on what has happened in the past so inferences can be made about the future.

The U.K. Ministry of Transport in the Portbury Study (Ministry of Transport 1966) used gravity models. The model worked quite well in predicting past cargo flows (Starkie 1967), but later studies have shown that the model's assumption of fixed market shares for each port resulted in extremely poor forecasts (Chu 1978).

The U.K. National Port's Council developed an elaborate econometric trade flow forecasting model. The model interprets statistical data of past movements of the relevant variables observed in other countries or in other spheres of economic activity and constructs mathematical functions which effect certain relationships expected to effect trade and tests these by statistical methods against historic data (National Port's Council 1976).

Input-output models developed in the 1930's have been used by Professor Leontief their originator to make detailed projections of seaborne traffic categories of cargo up to the year 2000 (Leontief 1979).

The trouble with the two models above is that they rely heavily on the availability of highly disaggregated high-quality statistical data, a requirement many ports and countries cannot meet. In addition those models are very maintenance intensive.

The analysis of movements of ships in port are constructed by and large on the basis of queueing theory (Edmond 1975) which is severely limited in the complexity of the system it can represent and therefore of the problems to which it can realistically be applied (Guise 1982). Wherever simulation is used, hardly any details are given to follow what was really done and how. This obviously could be due to the fact that such studies are confidential and have a high commercial value.

Finally the investment appraisal is partial and makes use of the available discounted cash flow techniques by making a trade-off between estimated port costs supplied by the civil engineers and the costs of ship waiting time to determine the cheapest strategy from the already existing or proposed ones, by comparing the costs and benefits of each strategy.

Most investment decisions reported in the literature (White 1972) focus solely on the relationship between the cost of increasing port capacity and the savings in ship waiting time.

Concerning investment appraisal (Goss 1978) points that .... there is no commonly accepted method of appraising proposals for investment in port facilities ....
in some instances this lack of systematic appraisal technique appears to have led to under-investment, over-investment or misplaced and mistimed-investment.

This study attempts to remedy the above mentioned limitations and difficulties in the following ways:

1. Building a forecasting model for seaborne trade linking the growth (or decline) in cargo tonnages to the economy and economic growth with minimum data availability.

2. Building a simulation model which provides detailed analysis of the movements of ships in port from the time they arrive to the time they depart. In order to avoid the prohibitive costs of simulation which is usually run on large computers, the simulation in this study is run on the micro (see chapter 6 of this study). It is an aim of this work that the models can be implemented on widely available computers and are transportable.

3. Developing an investment decision model resulting in the optimal berthing capacity for any future time of the planning horizon (1985 - 2000) through linking seaborne projections to simulation and to investment appraisal in a co-ordinated way.

This study is thus concerned with the relation between the growth in time of shipping and trade passing through the port on the one hand and the financial evaluation of the berthing facilities of the port on the other, that is, it examines the effect of changing demand on the berthing capacity of the ports, to arrive at a dynamic optimum investment programme at the strategic level for the commercial ports of Iraq, anticipating in advance the changes in future demand of different cargo vessels that are likely to use the port up to the end of this century in order to avoid the heavy costs of congestion or low berth occupancies.

In the next section a review and analysis of some recent studies conducted in this field will be given.

1.3 Background to Analytical and Theoretical Techniques

Most of the studies of port investment fall into two categories, the theoretical studies from which conclusions are usually derived from considerations of analytical models and the case studies which are derived from data collected in particular ports. All the studies can be grouped under three major headings:

(i) Studies based on queueing theory
(ii) Studies based on simulation
(iii) Studies based on other techniques

This section aims simply to introduce the nature of the research studies in port planning that use these three approaches. A full consideration of the techniques will be given in Chapter 4.

1.3.1 Studies Based on Queueing Theory

Studies based on queuing theory can be divided into two parts; studies using the mathematical analysis of queueing theory and studies using graphical solutions based on queueing theory. The latter avoids the burdensome task of computing numerous combinations of parameters analytically resulting in considerable time saving.

1.3.1.1 Studies Using Mathematical Analysis of Queueing Theory

An article by (Mettam 1967) gives a description of mathematical analysis of queueing problems as they apply to ships in port. Mettam shows how techniques developed in his article may be applied to the planning and design of ports to forecast the likelihood of congestion and costly delays as ships wait for a berth.

The method set out in this article is based upon a model in queueing theory. It assumes that the rate of arrival of ships is a random function of the Poisson law; the service time at the berth varies according to a negative exponential distribution, each berth is capable of handling all types of cargo; there are no berthing priorities; the cost of delays per unit time are equal for all ships and that the cost of these delays is a linear function of time.

Since all berths are assumed to be identical, it cannot indicate whether the provision of a specialised handling facility (e.g. dry bulk, or container) at a generally available berth would reduce congestion, it cannot test the efficiency of a particular system of berthing priorities, and it cannot compute whether all ships are delayed by a small amount, or whether most are not delayed at all while some are delayed for several days.

The assumption that the cost of delays is a linear function of time is far from realistic as will be seen later in this study.

A paper by (Taborga 1969) developes and tests a model for a dynamic growth policy for a seaport in an underdeveloped geographical region. This model has restrictive assumptions in that it assumes that only one homogeneous commodity will flow through the port and only one type of ship is assumed to operate in the port. The model is in fact an application of queueing theory. It represents the port as a set of multi-channels in parallel (a set of identical but independently operated berths) with an identical set of Poisson inputs and outputs.

A similar approach dealing with port capacity requirements was taken by (de Weille and Ray 1969) which deals with the question of how many berths should a port have, and uses a queueing theory model to determine how much waiting time would be incurred given the number of berths and the number of ships arriving annually.

The model used in this paper makes the following assumptions:

(i) The time between successive arrivals is a random variable and has a negative exponential distribution. As a consequence of this assumption, the probability that n arrivals occur within an interval of time t, $U_n(t)$ is given by

$$U_n(t) = \frac{(\lambda t)^n}{n!} e^{-\lambda t} \qquad 1.1$$

Which is a Poisson distribution and λ is the mean (or expected) rate of arrival.

(ii) The service time per ship is a random variable and has a negative exponential distribution with a mean service rate μ.

(iii) All the berths have the same service rate.

(iv) Service is on a first-come-first-served basis. On the basis of these assumptions, the mean length of the queue and the mean waiting time per ship were calculated using the following equations:

mean length of the queue
$$L = \frac{b\,\dfrac{a^M}{M!}}{(1-b)^2\left[\sum_{n=o}^{M-1} \dfrac{a^n}{n!}\right] + (1-b)\,\dfrac{a^M}{M!}} \qquad 1.2$$

mean waiting time
$$W = \frac{L}{\lambda} \qquad 1.3$$

Where M is the number of berths

$a = \frac{\lambda}{\mu}$ (the utilisation parameter for a berth)

$b = \frac{\lambda}{\mu . M}$ (the utilisation parameter for the system).

Although there is no mention in the paper of future demand except that it could be estimated using some growth rate, it is assumed that a unique estimate of future demand for each year could be presented, hence waiting times could be computed for different numbers of berths.

Waiting times (queueing times) could be converted to costs using waiting costs per ship per day multiplied by the total waiting time. Cost · benefit analysis is then used to arrive at the optimum number of berths for a certain year through comparing queueing costs with the costs of constructing and maintaining berths, if that year queueing costs of ships exceed the expansion costs of adding berths then the addition of berths should take place.

The model although very useful and interesting since the authors have gone into a great extent of extensive and lengthy calculations in producing tables of the total annual waiting time for 100, 200, 300, 400, 500, 600, 700, 800, 1000, 1500 and 2000 ship arrivals per year and for average service times of 1, 2, 3, 4 and 5 days and number of berths ranging from 1 to 18, has restrictive assumptions similar to the ones described above.

It implies that the demand function for each future year is completely inelastic, in other words, a certain number of ships will arrive regardless of costs in waiting times. The model also implicitly assumes that the berths are interchangeable, i.e. all berths have the same service time for all ships, while in reality a port might have some specialised berths and that different types and sizes of ships may have different service times.

In fact the authors do recommend that simulation is a better approach to solving problems of this nature.

(Edmond and Maggs 1978) examine how useful are queue models in port investment decisions for container berths. The authors favour queue models tabulated by (Page 1972) to those of (Mercer 1973). The latter might give better representation for scheduled arrivals, but the results are more difficult to evaluate and the errors introduced by the latter process will almost certainly outweigh any reduction in error by using very sophisticated models.

The authors warn that blind application of tabulated results such as for the average waiting times and multi-server models are not relevant to, and do not discriminate sufficiently between practical investment options.

Tides are the main factors neglected in the models considered in this paper. They impose a restriction on entry times to the ports which increase the importance of berth availability. The authors admit that although some queue models do give a reasonable approximation to some aspects of container operations, it is clear that no queue model can adequately represent the relevant operations of container terminals and hence simulation models may eventually be the only satisfactory way to represent the relevant operations, unfortunately such models are prohibitively expensive and time consuming.

1.3.1.2 Studies Using Graphical Solutions Based on Queueing Theory

(Nicolaou and Asce 1967) describe how the operation of a port is influenced by the number of ships arriving at the port and desiring to occupy berths, and the number of berths available in the port. The factors affecting the number of berths are evaluated in terms of the following interrelated parameters:

(1) Acceptable percentage of congestion in port.

(2) Acceptable percentage of berth occupancy.

(3) Optimum cost combination arising out of costs of idle port facilities and of ships waiting in port.

This paper describes criteria for the combined evaluation of parameters (1) to (3) on the basis of a simplified approach using graphical solutions. Based on Poisson law, and assuming that the average number of vessels is known, the values of the probability and expected frequency of vessels arriving in port are computed from curves prepared on the basis of tabulated values of probability as given by (Fry 1965).

On the basis of summation of probability values shown in those graphs, three sets of curves are prepared. The first set shows the relationship between congestion and cost index (average cost of ship awaiting berth/ average cost of ship awaiting berth + average cost of an idle berth (see Figure 1.1)), the second set of curves shows the relationship between congestion and berth occupancy and the third set shows the relationship between annual port capacity in tonnage, related to the number of berths available and the percentage of congestion based on a handling rate of 1000 tons per berth per day.

The graphical presentation of these three sets of curves allow the calculation of optimum port capacity for the required port and by inspecting the graphical representation it is possible to obtain general guidance to the suitable condition. The burdensome task of computing numerous combinations of parameters analytically or even by an electronic computer is avoided and considerable time can be saved.

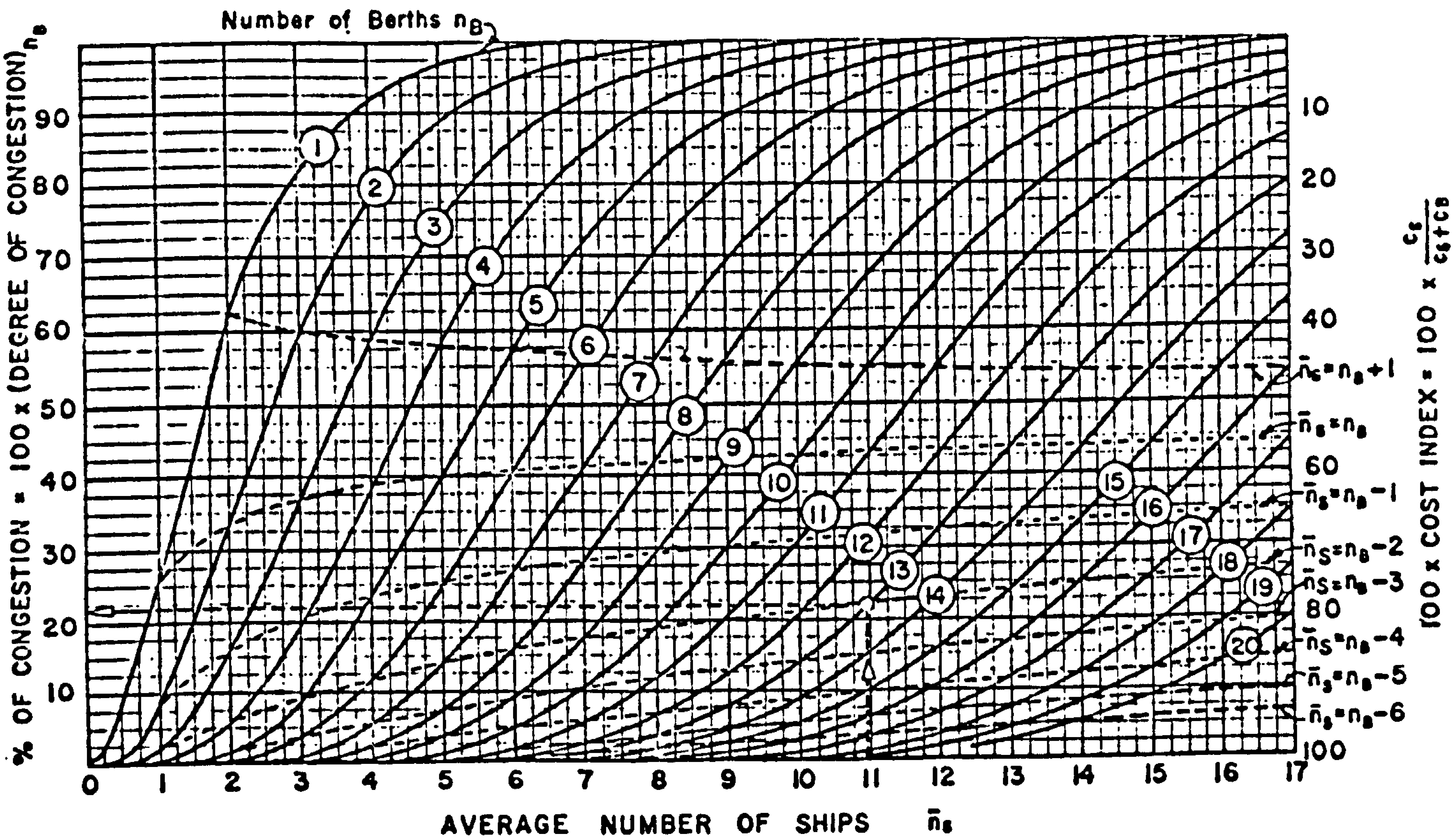

Fig. 1.1 Relationship Between Congestion and Cost Index

A similar approach was adopted by (Noritake and Kimura 1983) to find the optimum tonnage capacity for general cargo, which should be handled with a specific number of berths, and convenient graphs called 'optimum berth capacity curves' are obtained. In berth planning, it will be useful to show the range of the amount of cargo which is optimum to be handled by a specific number of berths. While Nicolaou and Asce took account of the costs for idle berths and idle ships, Noritake and Kimura say that the costs for berths and ships in port occur during both idle time and active time. Accordingly it may be suitable to consider both of these costs.

They define the cost in port with S berths as:

$$C_S^T = C_b TS + C_S T\bar{n}_S \qquad 1.4$$

where C_S^T = total cost for port with S berths during the period T

C_b = daily cost of a berth

C_S = daily cost of a ship

$\bar{n}_S$ = average number of ships present in port

Both sides of equation 1.4 are then divided by $C_S T$ in order to decrease the number of parameters involved. Thus

$$r_{Ss}^T = \frac{C_S^T}{C_S T} = \left(\frac{C_b}{C_S}\right) S + \bar{n}_S = r_{bS} S + \bar{n}_S \qquad 1.5$$

in which

r_{Ss}^T = ratio of total annual cost for port with S berths to annual ship cost, and

r_{bS} = berth-ship cost ratio.

Then curves showing the relationship between r_{Ss}^T and the traffic intensity (ratio of average arrival rate of ships to the average service rate of ships) for r_{bS} = 0.25 are obtained (see Figure 1.2).

The methodology used in this article is very similar to the one used by Nicolaou and Asce except for the 'optimum berth capacity curves' which use different axes and were developed for a variety of queueing models such as $M/M/S/\infty$, $M/E_2/S/\infty$ and $M/E_3/S/\infty$. Unfortunately the curves developed in this article are too clustered together and their use could very easily lead to misleading results in the optimum number of berths.

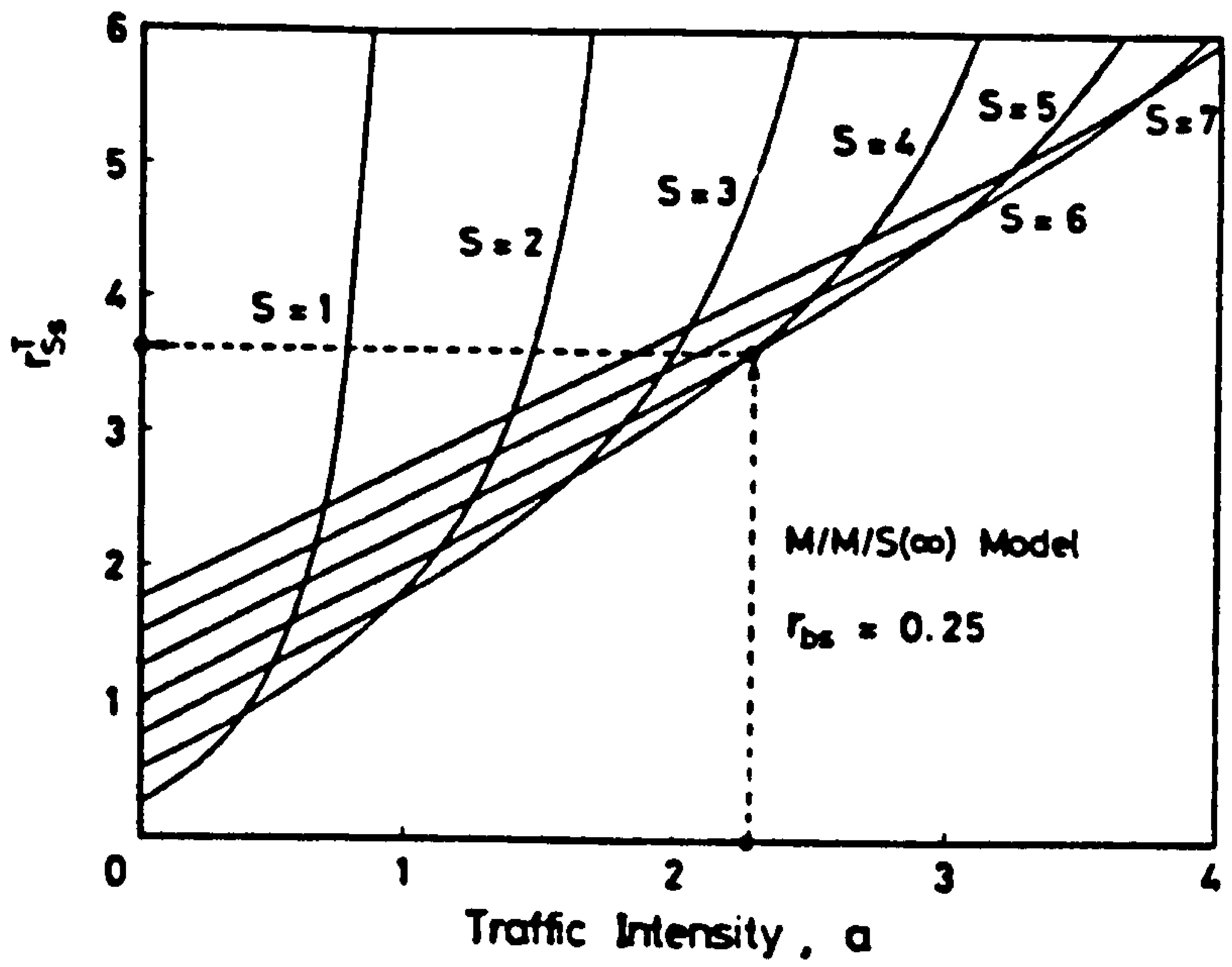

Fig. 1.2 Optimum Berth Capacity Curve (M/M/S (∞) Model)

Another study making use of tabulated and graphical presentations of queueing theory was conducted by (ITALCONSULT 1979) for the determination of the number of berths required for bulk solids in Jubail port (Saudi Arabia). In their study they use a set of curves giving the probability of waiting as a function of the number of berths available and berth occupancy. Once the probability of waiting time has been determined with the use of selected curves, very simple formulae consistent with the basic assumptions regarding the laws governing the random variables of the problem are used to yield the average waiting time of ships that wait. The latter is considered the critical factor in deciding if the expected costs incurred for demurrage of ships may be reasonably offset by providing additional berths.

It is stated in this study that the method adopted is definitely an approximation and more sophisticated methods such as simulation are recommended for more accurate results.

(Crook 1980) in his brief article presents some useful information in the form of tables regarding the relationship between berth occupancy and ship queueing time. This paper presents tabulated queueing theory results calculated by UNCTAD secretariat which can be used by port planners in dimensioning the number of berths for a port. The author does recommend, however, a more sophisticated approach, a simulation model, which attempts to estimate the ships time in port and reproduce the reality of the port.

(Jansson 1984) expands the use of queue models a step further. In the first part of his paper, a queueing model for the expansion of seaport capacity is developed with a view to deriving expansion paths for the capacity to load/unload ships and the capacity to accommodate cargo in transit storage. In the second part this model is used for calculating optimal charges on ships and cargoes, and for examining the likely financial result of optimal charging. The author makes no claim in his present study to have found a definitive solution to the last-mentioned problem, but believes that he has been able to bring into focus an interesting new area for theoretical and empirical research which has been extensively discussed in the literature, see for example, (Bennathan and Walters 1979).

Since this study is not concerned with port charges, port pricing will not be discussed any further.

As far as the first part of this paper is concerned, an important point that emerges from the discussion is that queueing theory may not be readily applicable to seaports as is commonly assumed. One fact that should be remembered is that where transit storage is applied the transfer of goods between sea and land transport is not a single-stage process. In these circumstances the conventional question regarding the optimum number of berths is not altogether relevant: it should be replaced by two interrelated questions regarding the optimum number of cranes and the optimum area for transit storage.

By considering the single-stage channel facility (a port section with one berth only), the author demonstrates through using elementary queueing theory, that if the service time is constant rather than following a negative exponential distribution, that is, the elimination of service time variability, reduces the mean queueing time by half. In the case of seaport operations this means that the expected queueing time may be reduced by either increasing the handling speed or by making ship calls more homogeneous, e.g. by specialising in servicing a particular type of ship or cargo.

The author then considers the multi-channel facility (seaport consisting of n identical berths) and demonstrates that the total queueing time decreases when demand and capacity increases at the same rate. The author states but does not show that the occupancy rate will steadily increase along the expansion path, while the mean queueing time will decrease, a logical result obtained by all researchers and shown in Chapter 7 of this study. This means that both the capacity cost and the queueing cost per unit of throughput will fall as throughput increases.

An interesting model taking account of the transit storage is then developed. Rather than measuring the output of the port by the number of ship arrivals (or the number of ships turned around), a two-fold output measure is adopted where the total queueing time is regarded as a function of the service outputs of two stages (total service time of ships and total storage of the cargoes) as well as the number of service stations in each stage as illustrated in equation 1.6 below.

$$Z = Z(X, Y, n_1, n_2) \qquad 1.6$$

where Z = total queueing time

X = total service time of ships

Y = total storage time of cargo

n_1 = number of service stations in stage 1 (cranes)

n_2 = number of service stations in stage 2 (transit storage)

Avoiding the complicated mathematics of queueing theory, the author constructs nomograms for those relationships that are of particular interest. By means of his present model, he claims that it is possible to produce nomograms for port capacity expansion paths by assuming different values for the ratio of the capacity unit cost to the value of ships lay time. In his paper he provides a single example of a capacity expansion path where he tries to answer two questions:

1) What is the optimum number of cranes of a specified type when the total crane-hour requirement is KX?

2) What is the optimum transit storage capacity, when the total storage space requirement is Y?

In the present model this is entirely a matter of trading off crane and storage costs against saving in queueing cost. The balancing factors are the number of service stations n_1 and n_2.

Given the costs of the service stations and the value of customer's time:

Total capacity costs $= c_1n_1 + c_2n_2$ 1,7

Total queueing costs of ships $= vZ(X,Y,n_1n_2)$ 1,8

Hence, the criteria for determining the optimal number of service stations can be stated:

Stage 1: $c_1 \leq v\left[Z(n_1) - Z(n_1 + 1)\right]$ 1.9

Stage 2: $c_2 \leq v\left[Z(n_2) - Z(n_2 + 1)\right]$ 1.10

where $Z(n_1)$ = total queueing time with n_1 service stations in stage 1
$Z(n_1+1)$ = total queueing time with n_1+1 service stations in stage 1

On the basis of these criteria it is possible to trace the expansion path for the number of successively higher levels of demand for port services given the values of c_1/v and c_2/v. The choice of a representative value of the relative factor prices will inevitably be rather subjective. The value of c_1 depends on the types of cranes that are installed on the quay and the value of c_2 depends on whether or not a transit shed is needed or not and on the applicable value of land. The value of v varies very widely depending on the size and type of ships calling at the port.

In the example used in the article c_1/v is set equal to $c_2/v = 1/5$ and the value of v to 30,000 Sw.Cr.

Two figures are developed in this paper, the first shows the relationship between the number of service stations with the total service time in days (see Figure 1.3) and the second shows the relationship between the number of service stations with occupancy rates, both used to calculate the number of service stations for each stage.

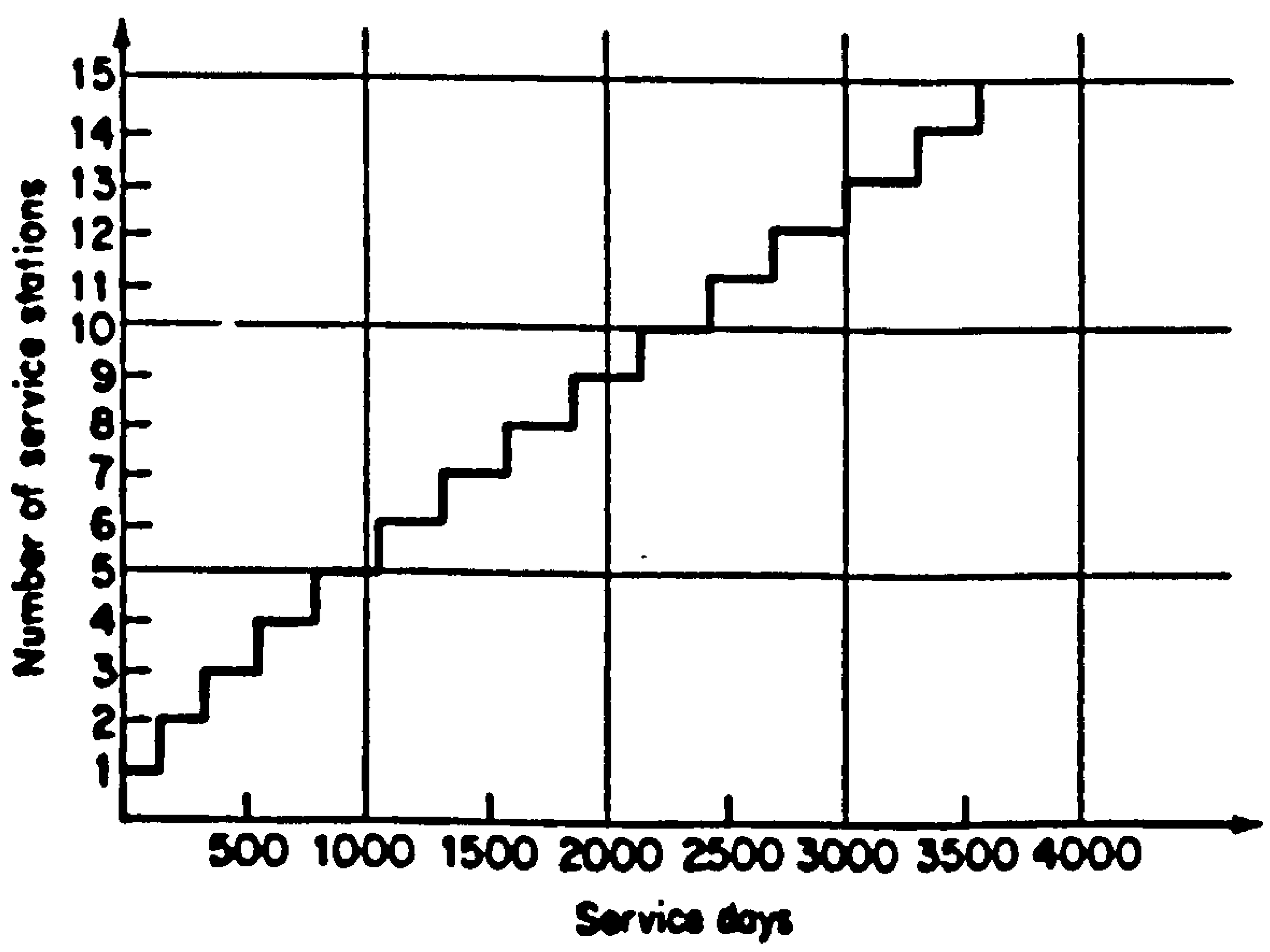

Fig. 1.3 Expansion Path for the Number of Service Stations

From the foregoing discussions, it becomes clear that the restrictive assumptions in the aforementioned papers renders them to be inflexible to be applied for the average tidal multi-purpose ports and their use might be restricted to specialised ports or terminals where only one type of cargo and identical ships are handled.

Such models cannot incorporate discontinuities such as shift work, tidal constraints and the sharing of more than one class of cargo and different ship types and sizes by the same berth.

1.3.2 Studies Based on Simulation

The queueing theory approach cannot be pursued to advantage, however, nor continue to be viable, without questioning the validity of the basic assumptions. One example is the widely accepted assumption for Erlang distribution for ship arrivals and service times which is necessary in order to make the general models generally applicable (Imakita 1978). For example the service distribution in the Iraqi ports follows a normal distribution (see Chapter 6 of this study).

A reluctance on the part of some researchers to accept the validity of such assumptions and since the system of interest sometimes is such that it cannot be represented adequately by any of the mathematical models, gave rise to a different type of approach, the simulation model.

One of the early works in this field was carried by (Heggie and Edwards 1968) where an investment programme was prepared for Port Swettenham from 1968 - 1977 on the basis of cost-benefit analysis using a computerised simulation model.

In this paper, the physical constraints that were likely to have an effect on the ports future operation were the shortage of wharves and more importantly, a shortage of wharves with specialised equipment on handling bulk cargoes. The problem therefore resolved itself into a question of devising a model that would enable future port congestion to be calculated on the basis of a number of alternative assumptions about new berths and additional handling equipment.

The simulation input was the pattern of ship arrivals, the length of the simulated year and number and types of vessels with their relevant cargo sizes. The number of wharves in a given year determined the presence or absence of congestion in port. This variable is constant for any one simulation run and can be altered to examine the effect on port congestion.

The cost-benefit analysis was carried out using the usual methods of discounted cash flow analysis. Costs and benefits were discounted to a base year 1968 at an opportunity cost of capital of 10% per annum provided by the government.

Different alternative strategies were evaluated and the cheapest chosen.

In fact in this paper the authors made a comparison between Mettam's method which is an application of queueing theory, as opposed to a workable cost-benefit method using discounted cash flow techniques. They conclude by saying that the complex characteristics of Port Swettenham and its traffic could more sufficiently be taken account of by applying a simulation model as opposed to the method proposed by Mettam.

The first step in improving the model as suggested by the authors will almost certainly be to build into it a tidal restraint.

A simulation model has been extensively examined by the Transportokonomist Institute of Oslo. The first version of its model was worked out under contract for (UNCTAD 1968) for the Port of Casablanca. The modified second phase of the model carried out during 1971 - 1973, under a joint project among UNCTAD, the Port of Bergen Authority and the Institute (Institute of Transport Economy, 1973). The operational relationships in this model are mostly based upon regression analyses from the actual data, for example, the number of gangs allocated to the ships is calculated:

$$G = C_1 + C_2.(\text{tons}) + C_3.(\text{length of ship}) \qquad 1.11$$

The Bergen constants were:

$$C_1 = \begin{cases} 0.82 \text{ domestic trade} \\ 0.56 \text{ foreign trade} \end{cases}$$

$C_2 = 0.0033$

$C_3 = 0.00444$

Similar formulae were used in the calculation of cargo handling rate (tons per gang).

The model takes into account both the seaward and inland side operations, that is, number of pilots, tugs, etc., on the seawardside and quays sheds .... etc., on the inland side.

The model produces a lot of output such as queues, use of gangs and equipment, cargo movements to and from sheds, use of storage, number of ship hours and cargo hours, number of ship arrivals simulated, use of pilots and tugs and use of berths. It was impossible to verify all output from the simulation because the corresponding statistics from real life were unknown. But, according to the Port Authorities of Bergen, the utilisation of quays, sheds, ...etc., seemed to be the same in the simulation as in the present port.

In contrast to the Institute's model, most other researchers have relied heavily on the theoretical distributions in their simulation as is the case with the "Port Simulation Model" (World Bank 1974).

Unfortunately, very little could be obtained about the Bergen and World Bank Models making it impossible to know what was really done and how it was done. In the Bergen model a report describing the results obtained from the simulation and some of the regression equations could be obtained but no details about the simulation. While the World Bank model, where only quay operations were simulated, it is merely a user's guide where very little is said about the model and only forms are provided where the relevant data could be filled and outputs can be obtained in terms of time related operations and their costs through the use of the World Bank computer, in other words, the model serves like any other simulation package available on the market but through filling the relevant forms rather than learning to operate the package.

(Nilsen and Abdus-Samad 1977) describe and compare the techniques of simulation and queueing in the planning of Puerto Cortes port in Honduras and suggest guidelines for determining the conditions under which the two techniques should be used.

The TAMS simulation package was used to carry out a capacity analysis of Puerto Cortes to assess future needs for berthing space.

Simulation models yield more detailed results than other methods such as queueing theory, and can be used to evaluate the total port complex including, channel entrances, movements within harbours, berth utilisation and landside storage. The value of the detailed information obtained from simulation must, however, be balanced against the high cost of developing and operating the model.

Queueing models are quicker and less costly to use than simulation, however, they do not have the flexibility of simulation models, are less adaptable to complex situations and provide less detailed results.

The authors conclude their paper by saying that there is no set rule that can be advanced showing that one tool is superior to the other. The superiority of one model on the other is rather predicted on the specific case being analysed.

(Guise 1982) in his article "Simulation of port systems - a basic guide" arrives at similar conclusions and suggests that computerised simulation can overcome many of the problems inherent in queueing theory techniques but is very time consuming and costly.

Referring to the article by (Edmond and Maggs 1978) and the last two articles, it becomes clear that simulation techniques are superior to queueing theory models when complex systems are concerned. The main disadvantage with simulation seems to be its high cost. All simulations of port operations conducted to date seem to have been carried on large computers such as the U.C.C. 1108, IBM 360/67, IBM 7094, etc.

It follows therefore that if simulations can be produced cheaply, it is recommended that they be used. This is what this study does through using microcomputers (see Chapter 6 of this study).

Simulation has the advantage over queueing theory in that it can be used for modelling a complex process which would otherwise defy mathematical description, because of the stochastic behaviour and non-linear characteristics of the process (UNCTAD 1978). Even though a mathematical model can be formulated to describe some systems of interest, it may not be possible to obtain a solution to the model by analytical techniques. While it is very difficult to study nonesteady states of queues by analytic procedures, it is quite easy to do so by use of simulation (Ackoff and Sasieni 1968).

In addition to the above (Naylor et al 1966) lists a number of other reasons for using simulation, the most important are listed below:

1. Simulation makes it possible to study and experiment with the complex internal interactions of a given system.

2. Detailed observation of the system being simulated may lead to a better understanding of the system and to suggestions for improving it.

3. Simulation is a useful training aid and an excellent method for research into system behaviour.

4. Simulation allows many alternatives to be tried. When new components are introduced into the system, simulation can be used to help foresee bottlenecks and other problems that may arise in the operation of the system.

5. Simulation can serve as a "preservice test" to try out new policies and decision rules for operating a system, before running the risk of experimenting on the real system.

6. Simulations are sometimes valuable in that they afford a convenient way of breaking down a complicated system into sub-systems each of which may then be modelled by an analyst or a team which is expert in that area.

7. Simulation enables one to study dynamic systems in either real time, compressed time, or expanded time.

1.3.3 Studies Based on Other Techniques

An alternative to the application of queueing theory was introduced by (Buckley and Gooneratne 1974). They argue in favour od using their average congestion cost function as a function of the traffic flow, the shape of which depends on the particular traffic congestion process in operation. They also investigate some aspects of the determination of timing for investment in the face of changing traffic flow over a period of years.

Their idea of introducing a congestion cost function was quickly taken up and modified for somewhat more generalised application by (Chang and others 1975) who have built a model for the planning of harbour capacities. In essence their work is devoted to the minimisation of the total cost of cargo transport (that is, ship costs plus inland transport costs) by using non-linear programming. They assume the non-linear function for ship waiting cost to be dependent only on the flow of cargo. Their costs for ship waiting time, however, are derived on the basis of queueing theory. One of the reasons why ship waiting time costs are included in the analysis is that such costs are passed on to the grain importers (to whom they make specific reference in the model) through surcharges and higher ocean transport rates.

The non-linear function is replaced by a piecewise linear function and the problem as they formulate it, is handled accordingly by linear programming as a transportation problem determining the optimal flow from each harbour to each destination (inland zone).

The analysis of investment planning for a port facing a continuously shifting, price-dependent demand has been tackled by (Devanney and Tan 1975) through the use of dynamic programming in their article examining the coupling of expansion policies for a port with short-run pricing.

A more recent paper (Dan Shneerson 1981) attempts to answer the questions whether, when and where investment in port systems should be made. Treating ports as public utilities, the main building block of the static criteria for port investment in this case is the comparison between queueing costs and the costs of expansion (adding berths, or adding cranes, whichever is applicable). If for a given predicted demand and queueing costs of ships exceed the costs of adding a berth, the investment should be made.

The extension from statics to dynamics was demonstrated by Devanney who shows this for a hypothetical case of a single port and a single commodity. Shneerson's analysis remains in the domain of dynamics and the problem of investment in a single port is extended to investment in port systems (Nigerian Ports). When there are many ports in the system, the throughput that will pass through any of the ports is assumed to depend partly on the facilities available in the other ports. The amount of cargo that will pass through each port will have to be determined by optimising the movement of goods to and from their origin and destination as they flow through the port system. Only after traffic has been allocated to the ports can investment be evaluated.

At each point in time the port authority will be facing two types of decisions:

- How to allocate traffic between the ports.

- How much and where to invest.

The objective function used within the model is the minimisation of the present value of total costs over the period 1985 - 2000. Total costs to be minimised include the costs of investment in ports plus the costs of queueing in ports plus the costs of inland transport, plus the costs of shipping subject to serving the forecast traffic demand. Demand was not considered in this objective function as it was assumed to be perfectly inelastic.

The calculations involved estimating demand by type of commodity for each period considered (which was supplied by Dr.J. Bigosinski in a separate study), then estimating supply of port facilities by type of facility, and, finally analysing the resulting equilibrium over the required port facilities

The capacity of existing break-bulk facilities was estimated on the basis of the actual handling rate in Nigerian ports. The total number of berths available in Nigeria during the period 1985 - 2000 was assumed to equal the number planned to exist in 1985.

For ports, queueing costs of ships were calculated. For each of the 21 ports, two curves of queueing costs - average and marginal - were calculated. These were calculated as a function of the capacity utilisation of the port and on the basis of specific parameters existing in the Nigerian ports.

Inland transport costs were based on a previous study (Scott 1972), railway operating costs were based on a study by (CANAC 1977), costs in ports were calculated on the basis of samples taken at the ports of Nigeria and published statistics at NPA and terminal design and inland connection costs were made by C.E.Tech., Inc.

The adequacy of Nigeria's port capacity to handle the forecast demand in 1985 was evaluated, so that the total costs were minimised. It became apparent that by 1985 port capacity would already be insufficient to accommodate demand and the possible solution of extending the existing port system to accommodate future increase in demand was discarded.

Hence the problem was reduced to evaluate the size and the staging of investment for a new ocean terminal either in the vicinity of Lagos or near Warri.

The decision on the size of investment at each period of time was based on minimising the sum of the following costs:

Investment costs for period t,

Inland transport costs and queueing costs in ports for period t,

The present value of queueing and investment costs from period t + 1 to the year 2000.

These costs were calculated for each location at intervals of 4 years. The solution to the dynamic programming investment problem resulted in a cheaper cost for the ocean terminal near Lagos. Throughout the period there will be no need for investment in conventional break-bulk facilities and 2 container berths are to be added every 4 years starting in 1985.

The author also provides the optimum port charges in his article as a by-product of the search for optimum outputs.

This article is similar to the article of (Chang and other 1975) as far as cargo flow is concerned except that dynamic programming is used instead of non-linear programming, however, in this article the author admits that by nature of the solution to the dynamic programming, at some periods of time occupancy rates of facilities will be low, and at others the ports will be more congested. The constraint that revenue should cover cost in each year is not imposed.

Queueing costs in this paper were calculated as a function of capacity which is an elementary method and should have been worked on the basis of queueing theory or simulation to obtain accurate results. There is also no justification as to why the total number of berths available in Nigeria during the period 1985 - 2000 was assumed to equal the number planned to exist in 1985 especially when the total amount of cargo to be handled in the year 2000 is more than two and a half times that of 1985 and increasing continuously throughout this period.

In conclusion to this section, most of the literature available on port planning gives very little details of how it was done, especially where simulation is concerned, which makes it very difficult to learn anything about the model and to assess it properly. In addition the application of any model to a particular port does not mean that it can be applied to another port with minor changes since each port all over the world has its special circumstances and characteristics. Moreover, text books concerning this field are virtually non existent which makes port planning studies that much more difficult.

This brief description of the above papers was given to provide a technical context for the study, as more detailed analysis of techniques will be given in Chapter 4.

In the next chapter a brief background about Iraq is provided with particular reference to ports and port related data. The study approach, boundaries and problem concepts together with problem formulation will be developed in Chapter 3. Theoretical analysis and research methodologies will be considered in Chapter 4, the various techniques that can be used in modelling port planning problems will be discussed, and a critique of these techniques including their appropriateness to particular port problems will be provided.

Chapters 5, 6, 7 and 8 describe the proposed modelling frameworks developed for this study, Chapter 5 will deal with the development of (seaborne projections) demand models based on consumption, production, gross domestic product and population. In Chapter 6 a simulation model is developed, this model is centred around a dynamic, stochastic computer simulation programme. It is dynamic in that port operations may be simulated for any desired length of time, thereby providing in hours estimates of the results of port operations simulated for years, and it is stochastic in that processes which vary randomly in actual port operations are represented to vary in the same way during the simulation. Chapter 7 gives a detailed analysis of the simulation results.

In Chapter 8 an investment decision model is developed linking the capital costs of berthing facilities with the queueing costs of ships obtained from the simulation to arrive at an optimum investment decision at any future time period. Finally, Chapter 9 draws conclusions about this study and gives some recommendations for further research.

CHAPTER 2

IRAQ: GENERAL BACKGROUND

Since this study is concerned with the planning of the ports of Iraq up to the year 2000, it is felt necessary to provide a general background about the country as a whole. After giving a few introductory remarks about Iraq's geographical location, its population growth rate .... etc., the main features of the economy and economic planning are then discussed. A brief account of the physical infrastructure of the highway and rail networks is provided next, and finally the trade and ports together with maritime trade and ports data is given. It will be seen in this chapter that maritime trade has increased rapidly during the years 1974-79 almost doubling due to the impressive growth rates achieved in the economy, thus necessitating the importance of port planning since 90 percent of the country's imports and exports are transported as maritime cargo.

2.1 Introduction

IRAQ 1979	
Area(square kilometres)	434,000[a]
Population(persons)	12,804,000[b]
Gross Domestic Product (M.I.D.)	7,520
GDP per Head(I.D.)	587.3
Value of Imports (M.I.D.)	1,739
Crude Oil Production (000bpd)	3,400
Seaborne Imports (000 Tonnes)	5,423
Rate of Exchange: 1 Iraq Dinar(I.D.) =	$3.333

(a) Excluding Iraq's share of the Saudi-Iraq Neutral Zone

(b) Estimates

Iraq is part of the Arab Nation, located at the northern east of Arabia. It is bounded on the north by Turkey, on the west by Syria and Jordan, on the south by Kuwait, Saudi Arabia and the Arabian Gulf and on the east by Iran.

The total population recorded at the October 1977 census[1] was just over 12 million persons of whom 3 million resided in the Greater Baghdad area. The annual growth rate has averaged 3.4 percent in recent years. Almost half of the total population was aged under 14 years in 1976, providing the foundation for rapid future growth. Assuming a continuation of recent trends, the population would exceed 25 million by the end of the century.

2.2 Economy

With an area of 434,000 square kilometres and a population of over 14 million persons, Iraq is one of the largest and potentially one of the most important countries in the Middle East.

According to World Bank data, economic expansion, stimulated by the country's oil receipts was rapid during the 1970s, averaging more than 12 percent per annum between 1970 and 1978. The precise size of Iraq's oil revenues is not known but it has been stated that they could be the second largest in the world, and, certainly the economy is dominated by the oil industry. The country is also rich in other minerals, principally sulphur and phosphates, output of which is to be substantially increased during the next five years.

In the lastest five year plan (FYP) covering the period 1981-1985, expenditure is projected at no less than $133 billion. Particular attention would be devoted to agriculture, as food imports now represent a considerable drain on the nation's finances. At present only about

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1 Central Statistical Organisation, Ministry of Planning

one quarter of the total cultivable land is being utilised. Expenditure in this sector has concentrated on various land improvement projects including extensive irrigation schemes, while the introduction of more intensive form of agriculture with improved technical assistance will lead to increased agricultural output. The FYP expects self sufficiency in foodstuffs to be attained by 1985. Substantial investments will be made with foreign assistance in manufacturing industry and that large sums will be allocated from oil revenues to infrastructural development, including road and rail transport with emphasis on increasing the ports capacity.

An indication of the rapid pace at which Iraq is building up its economic framework can be guaged from the fact that total expenditure on consrtuction projects accounted for 40 percent of GDP in 1975, and was almost 60 percent higher than the combined total for Kuwait, Bahrain, Qatar, the United Arab Emirates and Oman. By 1980, Iraq's construction expenditure was more than twice as great as their total.

Variations in Gross National Product tend to derive mainly from changes effecting the oil and agricultural sectors which, despite the rapid growth of manufacturing industry in recent years, are still outstandingly the main contributors to national wealth.

Private sector development has been curtailed by nationalisation and the public sector exercises control over the country's trade and is responsible for the purchase of nearly all imports.

Iraq is expected to make substantial economic progress, its drive towards industrialisation is having a modest success. The future prospect for agriculture is very good, but nevertheless, the economic progress will remain vulnerable to fluctuations in oil revenues until the ambitious industrial development plans come to fruition. The major agricultural and irrigation projects now underway are likely to make significant contribution to local food supplies well before the late 1980s, so that food imports, and with them dependence on the North American grain producers, maybe expected to fall sharply before the end of the decade.

The conflict with Iran is obviously having a detrimental effect on Iraq's short term economic prospects, but the country's substantial hydrocarbon revenues will eventually provide the government with the financial resources to develop the country's economy well into the next century. When the current difficulties are overcome, economic growth should resume the same impressive rate seen during the 1970s. In the meantime reduced oil revenues combined with financial support from other countries should enable the economy to stay reasonably on course[1].

2.3 Economic Planning

Most developing countries today believe planning to be a necessity. As Iraq has a long experience of development planning dating back more than four decades, the authorities have been strongly influenced by outside ideas, initially in the pre-revolutionary period of 1958 from the west but later by the Soviet ideas after 1959. In the 1970s Soviet influence over Iraq's economic affairs lessened and there is no indicator of it reviving. Instead, there has been an earnest attempt to discover planning methods which are best suited to Iraqi conditions, rather than trying to conform with either Western or Soviet planning models.

Iraq started to adopt planning as early as the 1940s with the country's transition to an oil-based economy. It was realised that the government would have to play a major role in economic activity if the oil revenue was not to be wasted fruitlessly on current consumption. The emphasis was on creating a well organised centralised authority for administrating oil revenue expenditure and on ensuring that funds were dispensed in an orderly fashion so that economic stability would prevail. At the same time it was acknowledged that the private sector in Iraq was unlikely to be capable of modernising the economy, especially as it was so limited in size[2].

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1 Iraq, An economic report published by the Market Intelligence Department, National Westminster Bank, November 1981.

2 M Ziwar Daftari, The Planning and development of Iraqi Industry 1980

The plans in the fifties were continually being revised and redrafted before they reached the implementation stage. One reason for this was that the oil revenues on which the planned expenditure was based were continually being revised upwards, a further reason was the presentation of reports by outside bodies or experts called in to study the country's development prospects, such as the World Bank Mission in 1952[1].

Iraqi planning methods were fairly basic in the 1950s, the usual procedure adopted being to forecast the likely level of oil revenue, and then draw up a spending programme in the light of these projections. No attempt was made to formulate development objectives in the light of the country's needs, it was solely an anticipated oil resources which determined what was to be done. The development plans were a mere listing of possible projects. The construction sector had the best record of implementation and the industrial sector the weakest. It was not until the 1970s that the implementation record for industry reached a consistently high level, indicating that the planners were on target.

After the 1958 revolution planning methods changed less than planning targets and the approach remained partial than comprehensive although detailed five year economic plans were prepared. The detailed economic plan for 1961-65 had a modest success. The plan for the 1966-1970 period was a much more sophisticated document than the detailed economic plan of the previous five years and for the first time consistent and quantifiable criteria were used for project appraisal, so that possible investment undertakings could be ranked in an order of priority. Two criteria were used, capital output ratios and capital to foreign exchange savings ratios. Under the first criteria, projects with higher output in relation to capital investment were preferred over projects with lower output. The second criteria gave priority to projects with higher ratios of foreign exchange saving per unit of investment over those with lower saving. The implementation of the 1966-70 plan was not notably much more successful than the implementation of the previous

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[1] International Bank for Construction and Development, The economic development of Iraq, 1952.

plan has been. The 1971-75 plan marked a major change over the previous plan, both in terms of planning methods and development strategy. The authorities adopted a macro-economic rather than a micro-economic approach. Targets were given for growth, consumption, exports, prices and employment.

The major change in the late 1970s in planning has not been in methods or strategy but in the machinery for administration of the development effort. Much useful research has been carried out within the Planning Ministry and the projects successfully implemented are concrete examples of the achievements made; productivity has improved considerably and waste resulting from utilised capacity has been significantly reduced. A five year plan is prepared for the following sectors:

- Agriculture, forestry and fishing
- Mining and quarrying
- Manufacturing industries
- Construction
- Electricity and water
- Transport, communication and storage
- Wholesale and retail trade, hotels and others
- Banking, insurance and real estate
- Services sectors

The five year plan 1981-85 for the transport sector was mainly based on the expected growth in economic activity, expected increase in national income and thus per capita income, and the expected increase in population growth.

2.4 Transport Infrastructure

2.4.1 Highway Network

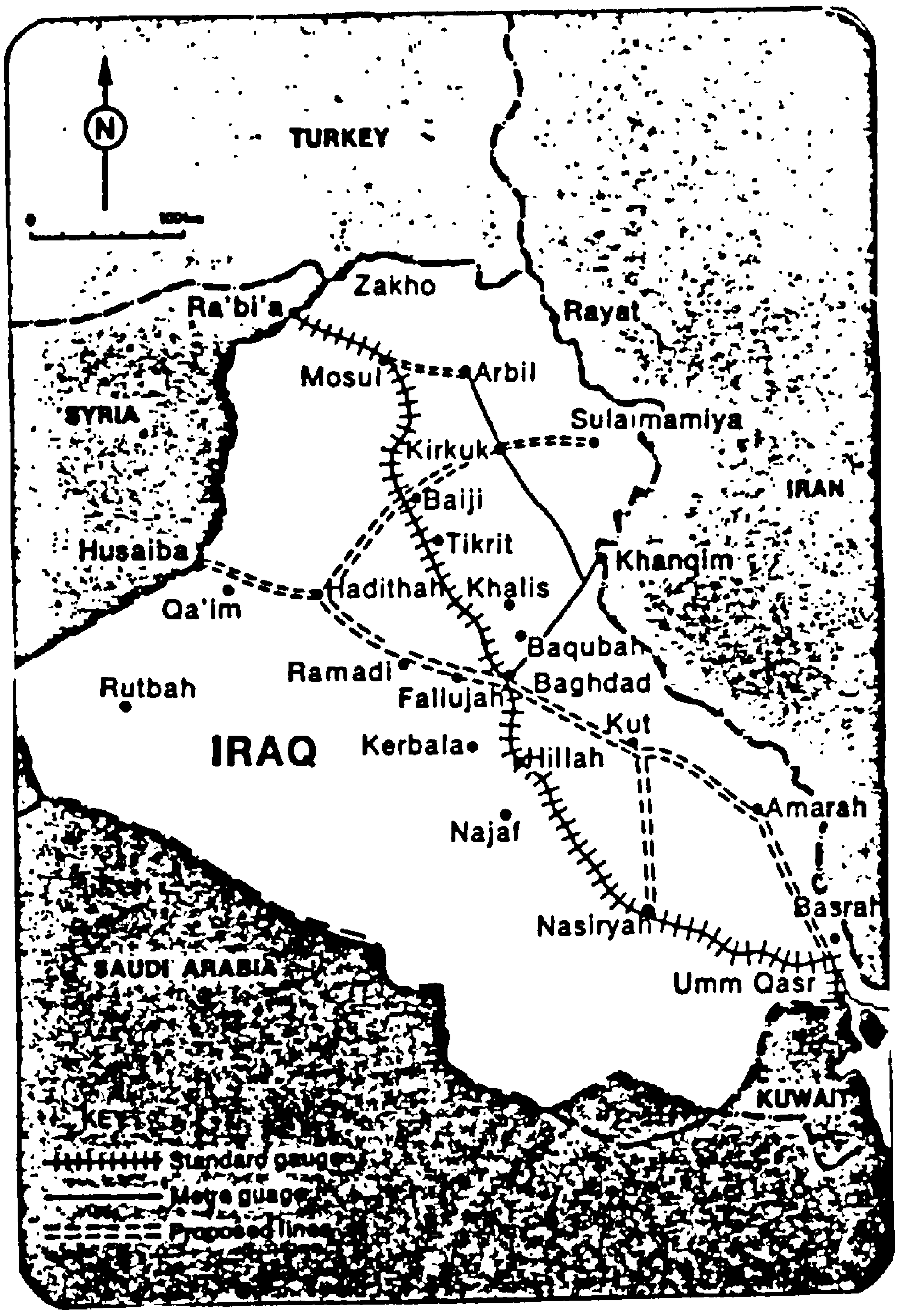
Only in the last ten years has progress been made in improving Iraq's overall infrastructure and even now it is still insufficient for the envisaged economic development. However, every effort is being made to improve the facilities. Most of the highway network is single carriage-way, although near Baghdad most has been improved to dual carriage-way and motorway standards. Since 1970 more emphasis has been placed on the upgrading of the existing paved roads to modern standards, and the paving of the earth roads, rather than on the improvement of existing roads to dual carriage-way standards.

Links between the main centres, such as Baghdad, Mosul and Basra, are of reasonable quality, and major improvements have taken place between other major city links and on a number of bridges across the Tigris and Euphrates. The major proposal some five years ago under construction is a 1,200 kilometres dual carriage-way to motorway standards, from Jordan to Baghdad, and to Basra and Kuwait as part of the Trans-Arabian highway. The ring roads around the main population centres have top priority and the one in Baghdad is nearing completion.

As far as freight transport is concerned, the principal agency concerned with freight haulage is the General Establishment for Transport of General Cargo, which is responsible for freight movement through Iraq and abroad. Since July 1977 this Establishment has been responsible for handling all international road traffic. It was found, however, that the available transport could not handle the volume of traffic and the company had to allow privately owned vehicles to serve the ports also. Future developments within the transport sector, for example container handling are likely to be the sole perogative of the General Establishment.

2.4.2 Railway Network

The national existing railway network total approximately 2,550 kilometres, evenly divided between standard and metre gauge. The standard guage lines are from Baghdad to Basra and UmQasr, and from Baghdad to Rabia on the Syrian border via Mosul. There is also a metre gauge line from Baghdad to Basra in the south with branch lines to Kerbala and Nasiriyah, and from Baghdad to Kirkuk and Arbil in the north with a branch line to Khanqim. The existing standard gauge line will replace the metre gauge line between Baghdad and Basra.



The General Organisation of Iraqi railways has undertaken a series of feasibility and design studies to convert the rail network into a major component of the national communication's system, the most important proposal is Baghdad - Husaibah line with branch lines to Akashat and Fallujah. Specifications were prepared and invitations to tender the construction have been issued. Also being considered is the conversion to standard guage of the Baghdad - Khanqim line, a feasibility study has been undertaken and work has been approved. The high speed line Baghdad to Basra and Um Qasr via Kut and Amarah with a branch line from Kut to Nasiriya has been designed.

Total freight movement has increased from 5.1 million tonnes in 1976 to 6.2 million tonnes in 1979. Of the total 1976 tonnage 3.4 million tonnes were carried on the Baghdad - Basra line illustrating the importance of the rail network for internal freight movements to and, particularly, from the ports. Passenger movement by rail in 1976 was roughly 3.5 million persons, however, this movement by rail presents only a small proportion (8 percent) of the total public transport movement within the country. The main competition is from inter-city buses, which offer cheaper, faster and more frequent services.

2.5 Trade

The heavy inflow of oil income resulted in a sharp rise in both value and volume of imports to Iraq in the period 1974 - 1979 (see fig 2.1). In tonnage terms, a large part of the increase was due to the greatly expanded demand for construction materials (such as steel and timber) which accounted for over 25 percent of the total volume of seaborne imports in 1979. On the other hand, demand for imported food stuffs principally grains accounted for over 30 percent of the total volume of imports in the same year. With increased agricultural output due to the major agricultural and irrigation projects now under way, food imports are expected to decrease sharply before the end of this decade, while construction material and manufactured goods are expected to maintain the same steady rise well into the next century.

Manufactured goods and foodstuffs broadly represent the potential market for container traffic which, while only just beginning to penetrate the Iraqi ports in 1978, is expected to expand very rapidly in the period up to 1985. It is expected that a high percentage of all cargo suitable for transport in containers will infact be containerised before 1985. In a study of the Gulf ports in 1977 undertaken by Peat, Marwick, Mitchell & Co., it was estimated that by 1982 more than 50 percent of containerisable goods (boradly speaking all goods other than bulk cereals, cement, constructional steel and timber and vehicles) imported to Iraq will be arriving in containers. Container traffic for Iraq in 1982 was estimated at 800,000 to 1,200,000 tons (roughly 120,000 TEU) at a penetration rate of 40-60 percent.

Iraq's non-oil exports have shown little change either in composition or in real value between the years 1974 - 1979 (see fig 2.2). They have tended to stagnate because of growing local demand, and also

Figure 2.1 SEABORNE IMPORTS

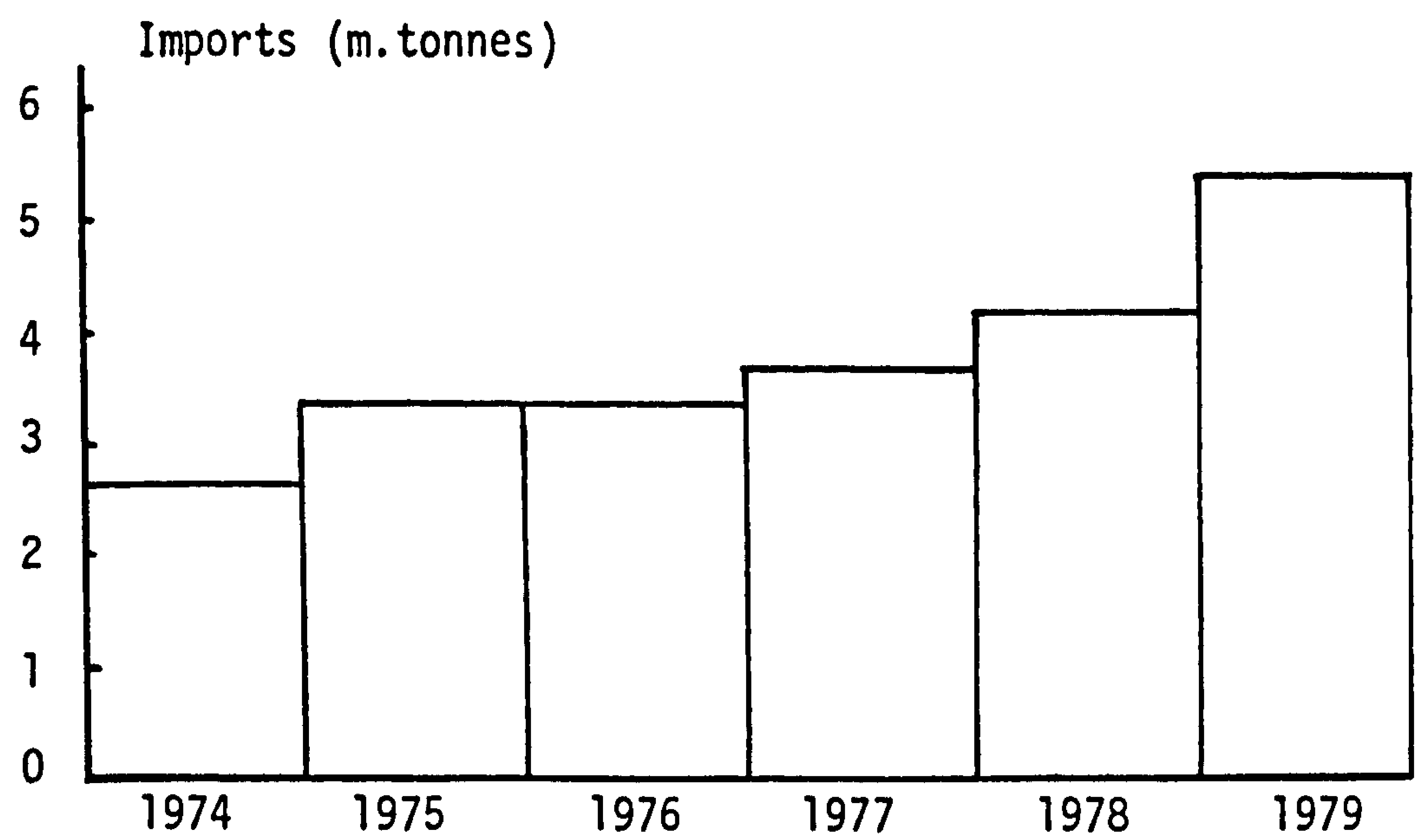
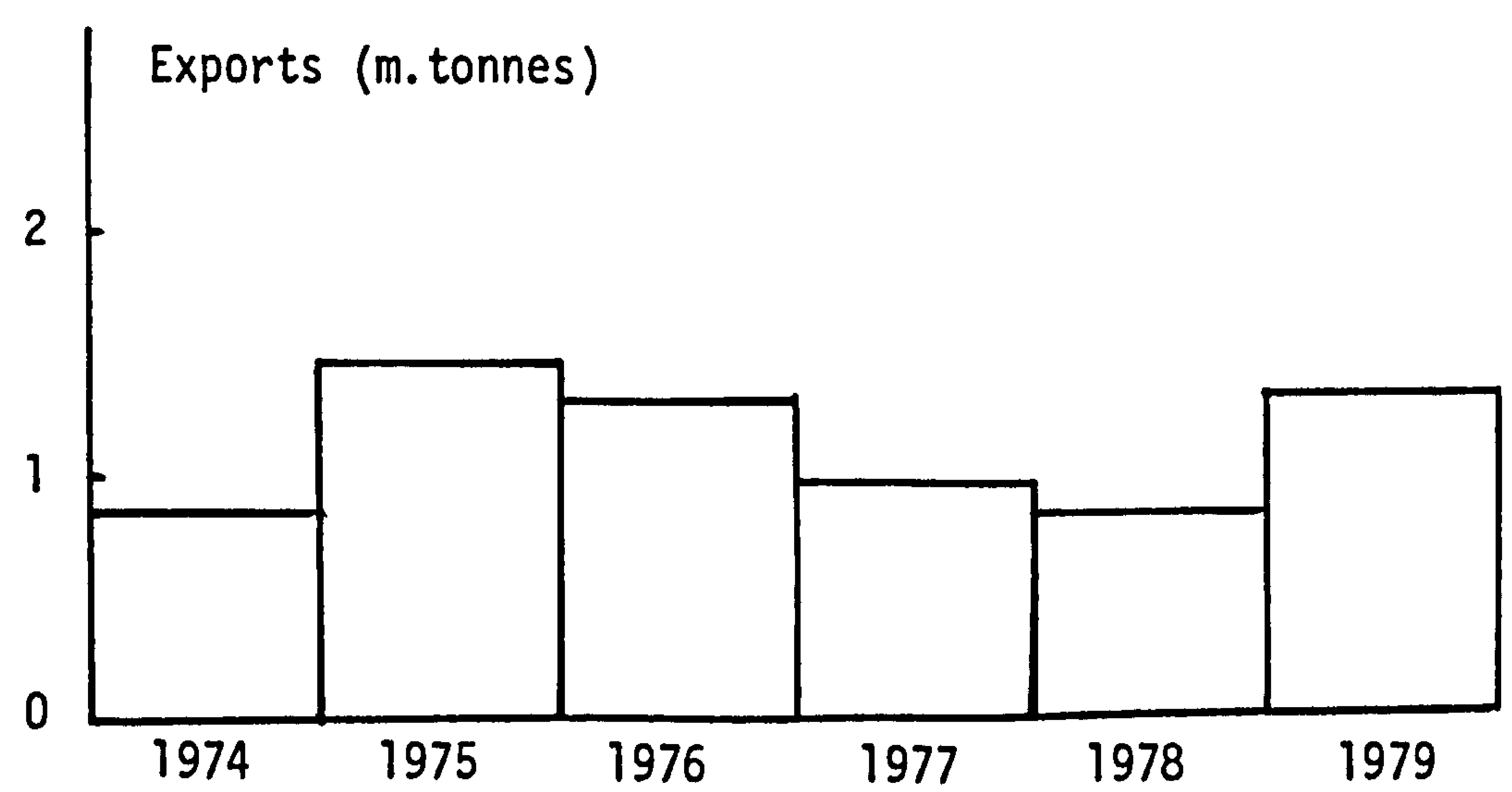


Figure 2.2 SEABORNE EXPORTS



because domestic manufacturing is not export orientated.

2.6 Ports and Ports Data

In 1980 the ports were closed because of the Iraq-Iran war and no details could be obtained beyond 1979. There are three commercial ports in Basra, Basra, UmQasr and Khor Al-Zubair, a plan for Basra is shown in Figure 2.3, but no plan could be produced for the other two ports. Until 1977, imports were handled almost exclusively at Basra port, as imports increased sharply in 1978 and 1979 more berthing capacity was required and since there is very little room for expansion in Basra more berths were constructed at Um Qasr to meet the growing demand.

In 1979 Um Qasr handled almost 2 million tonnes of imports and exports and most of the expansion is to take place in Um Qasr and Khor Al-Zubair ports in future. The cargo tonnages handled by each port in 1979 were as shown in Table 2.1

Table 2.1 CARGO TONNAGE HANDLED BY IRAQI PORTS

PORT	TONNES	
	IMPORT	EXPORT
Basra	4,170,078	480,563
Um Qasr	1,252,956	707,868
Khor Al-Zubair	--	146,709
TOTAL	5,423,034	1,335,140

The existing berthage in 1979 is shown in Table 2.2. In the FYP covering the period 1981-85, the berthing capacity of the ports is to be increased to over 26 million tonnes by 1985, i.e. an increase of over 270 percent in six years or at an annual increase of 18.5 percent.

As soon as the ports will be in operation again, Basra port will handle general cargo, grains, vegetable oil and sugar; Um Qasr port will be expanded to handle the rest of the general cargo traffic and containers, while Khor Al-Zubair will be restricted for fertilisers, phosphates, sulphur and urea exports.

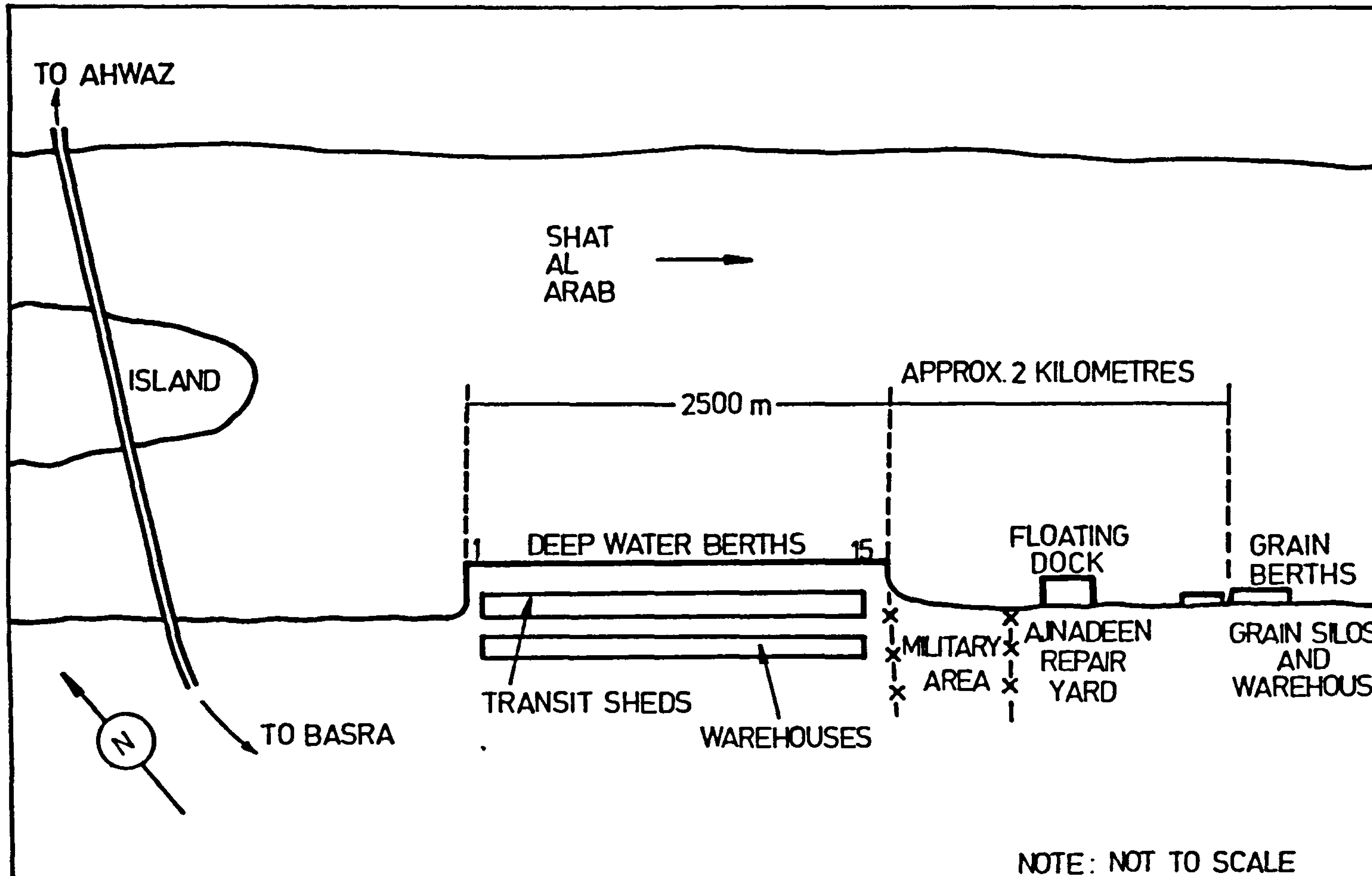


FIGURE 2.3 BASRA PORT

Table 2.2 EXISTING BERTHAGE FOR IRAQI PORTS

BERTH NO.	BERTH LENGTH(m)	DREDGED DEPTH(m)	CAPACITY (Ton/Year)	MAIN PURPOSE
BASRA				
1 - 13	167	9.6	300,000	General Cargo(GC)
14, 15	167	10.0	300,000	GC/Bulk Grain
Grain(2 berths)	200	10.0	400,000	Bulk Grain
Vegetable Oil(1)	170	9.6	400,000	Vegetable Oil
Urea (1)	170	9.6	400,000	Urea
UM QASR				
1 - 4	170	9.8	300,000	GC
5 - 7	170	9.8	300,000	Bulk Sulphur
8	170	9.8	300,000	GC/Cement
9	250	10.0	500,000	Container/Ro-Ro
KHOR AL-ZUBAIR				
1	250	12.0	550,000	Fertiliser Export

CHAPTER 3

STUDY APPROACH

A port is a gateway whose function is to transfer goods between seaborne and inland transport modes. The operation of a seaport is a highly complex process involving the operations of discharging, transferring, storing and delivering the goods to their final destinations. This requires the provision and operation of many facilities such as harbour crafts, navigational aids, tugs, pilots ... etc., on the seawardside, berths where ships dock to discharge their load, fork lift trucks, fleet of vehicles, railways, sheds and warehouses ... etc., on the inland side. The port may have one or more of the following objectives:-

i. Maximise flow through the port
ii. Maximise profit from port operations
iii. Achieve required capacity at minimal cost
iv. Achieve minimum total transportation cost
v. Other.

In Chapter I it was mentioned that the goal of this study is to establish a tool for long-term planning of a port system by which it is possible to work out a dynamic programme for investment in berthing facilities. It is, therefore, in order at this point to clarify as to which parts of port will this study address itself to and its aim.

3.1 Study Boundaries and Problem Concepts

Within the broad national strategy, the development of each individual system of the port must be planned. Port planning and development consists of a short-term programme and long-term planning. The short-term programme is to improve the management, the present facilities and their use. The long-term plan consists of a view of the future situation as it will be seen after a series of individual developments will be carried out. However, it does not try to say whether and when each will occur, since this depends on the traffic development. The short-term programme of immediate practical improvements for the use of existing facilities can, however, go ahead independently of the long-term plans.

This study is concerned with long-term planning, namely, in determining berthing capacity needed to handle future demand through comparing different port configurations under equally efficient conditions, that is, given the projected demand what berthing capacity should be provided or to what level should the port be expanded. It will not deal with the daily management and operation of the port or the improvement of present facilities and, therefore, disregards the details of shed operation, cargo handling, back of the port operations on the inland side and the number of tugs and pilots on the seawardside. The objective of this study then is to achieve the required berthing capacity to meet future demand at minimal cost.

Investment in berths cannot be foreseen or decided upon by intuition or on knowledge accumulated from past experiences, it will obviously depend on the future traffic volume of shipping and trade passing through the port at any future time period. To illustrate the importance of future traffic volumes especially in developing countries, take for example a one million tonne level increasing by 10 percent each year, after twenty years it becomes 6.7 million tonnes which is a very substantial increase and illustrates the need for careful planning. It is, therefore, essential to start this study with traffic forecasts and to estimate as accurately as possible the volume of commodities (imports and exports) and the types and vessels carrying them in future.

If ships arrived at the port with complete regularity and the time taken to discharge and load ships were constant, it will be a simple matter to determine the number of berths and the berthing capacity that would guarantee both the full utilisation of berths and the avoidance of queues by ships. Unfortunately, such an ideal situation can never exist. Ships arrive at a port at random. In addition the time taken to discharge and load ships varies considerably owing to the variation in the types and sizes of ships and the quantities and types of cargo handled. As was mentioned earlier in Chapter 1, this is essentially a queueing process and requires the application of queueing theory if it can be applied or simulation in order to determine average waiting times of ships, queue lengths, berth utilisation and idle times ... etc.

The combination of variable ship arrival rate and variable ship working time means that a very high berth occupancy could only be guaranteed at the expense of a continuous queue of ships. Similarly, that ships would never have to wait before being able to berth could be given at the cost of extremely low average berth occupancies. Neither of these two alternatives is acceptable, what is required is a compromise between these two extremes. This obviously calls for investment appraisal to arrive at the optimum capacity.

The concepts of this study are, therefore, centred around the three blocks above, forecasting future demand, simulating the arrival and departure of ships at the port and finally building an investment model through which optimum investments in berthing facilities can be achieved.

It is not necessary to use complicated mathematics to demonstrate that a port response to an increase in traffic will lead to congestion which can be serious and long lasting. Suppose, for example, that a terminal can handle 60 ships a month, a 10 percent increase in traffic - six additional ships a month - will result in an extra queue of 18 ships after 3 months. If the rate of handling ships at the port is increased by 10 percent and this increased rate is maintained continuously, it will only stop the congestion from getting worse, but there will still be a permanent queue of more than 18 ships and long waiting times. If the rate of working were increased by 15 percent over the original rate so that the port could handle 69 ships, it will still take the port a further six months to clear the congestion. Furthermore, under congested conditions improvement in handling rates are extremely difficult to introduce and maintain and obviously cost much more than if they were properly planned. While emergency action can be taken in such circumstances, the possibility of emergency action is not an acceptable reason for restricting investment. This stresses the need for careful planning and analysis particularly when long-term planning covering a horizon for the next 15 or 20 years is considered, otherwise, the situation will be out of hand resulting in very long queues, and long waiting times resulting in very heavy costs like the ones cited in Chapter 1.

Although the immediate benefit from port investment may accrue, not to the investing authority, but to the users of the port, many of whom will be foreign, however, in the long run, the port and the country as a whole will derive considerable benefits from the extension and modernisation of port facilities. It is also quite in order for the authority to invest in more capacity than the economic optimum especially when demand is growing and when it has good reasons for doing so, for example, in order to provide a deliberately higher level of service to users as a promotional policy to encourage the use of the port or to foster local industry as part of a regional development policy. There is not likely to be any good case for investing in less than the economic optimum except where the decision authorities know that in a wider context the growth of the port should be restricted when traffic is to be diverted to other ports or other modes of transport.

A group of berths which rarely or never runs its queue of ships to zero is loaded above the economic optimum. The normal situation should be that immediate berthing is possible for a majority of vessels arriving, but the fact that this is the case at a given port does not mean that further investment cannot be justified.

When determining the capacity needed to handle the demand forecasts, it makes little sense to treat the port as a single entity, however small the total volume of traffic. Each class of traffic must be examined separately and separate forecasts of tonnage, ship and level of service must be made for each. The traffic must be assigned either, individually or in combinations of types to the berth groups as the case may be in the port, then the appropriate capacity for each berth or group of berths must be designed.

Finally, a word about the benefits derived from port investments which are:

i. The transport cost savings made possible by the use of ships which can carry the goods at lower cost per tonne of cargo (e.g. larger or more modern ships encouraged to use the port).

ii. The reduced turn-round time of ships when very little or no congestion exists, this is often the largest benefit.

iii. The reduced period goods spend in port and on ships. This will free capital tied up in goods and thus give indirect financial benefits to the country as a whole.

3.2 Problem Formulation

Planning in Iraq is carried on five year plan basis, every five years a plan is prepared covering all sectors of the economy, and expenditure for each sector is allocated as deemed necessary. Since the horizon of this study extends to the year 2000, and since the expansion of the port cannot proceed on a continuous basis or in series of small steps, investment decisions will have to be made every five years, that is in 1985, 1990, 1995 and 2000 to conform with national planning and the nature of port investments. Nevertheless, the investment model will be built in such a way to cater for decisions on a yearly or two yearly basis ... etc., should such a need arise in future.

As was mentioned in the previous section, the starting point of this study should be concerned with future demand. Traffic forecasting requires a combination of mathematical and economic knowledge and it is important to bear in mind the very high degree of uncertainty in any forecast especially when ports are concerned because they are particularly vulnerable in view of their long planning time-scale and limited ability to influence demand, especially in developing countries all forecasts should be linked with the national development plans.

It is difficult to rely too much on long-term forecasts, for the most penetrating analysis of forecasts cannot be relied upon more than a few years in advance. Even when high and low trends are made for long-term planning, it is sometimes found that the actual level reached lies outside these limits. It is, therefore, recommended and sometimes necessary to review the forecasts every few years. One example is the forecasts of seaborne exports of feed grain made in three independent studies by experienced consultants in 1967 in the United States[1]. Even though one of the consultants provided a wide range of possibility between a high and a low estimate of the trend, the actual figure reached in 1973 reached a level that even the highest forecast did not predict before

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[1] Port Development in the United States, National Academy of Science 1976

1985.

Future ship calls to a port is generated by cargo passing through the port. Further will the cargo traffic be generated by the production, consumption, population and economic growth. It should, therefore, be possible to determine the dependency between the cargo volumes on the one hand and the traffic generating factors on the other. When the relations are determined by analysing past data, it becomes possible to estimate accurately ships traffic forecasts from forecasts of cargo; and forecasts of cargo volumes can be estimated from forecasts of production, consumption, population and economic growth.

The fact that over the last few years a particular class of traffic has been increasing does not necessarily mean that the trend will continue into the future. In most cases in developing countries the reasons will be one of the following:-

i. Traffic is directly dependent on gross domestic product
ii. Traffic in a special commodity or product has been deliberately developed or run down, e.g. self sufficiency in a major food stuff, development of new industry ...etc.
iii. A gradual shift in transport technology or routeing is occurring from break-bulk shipments to containers, from maritime to overland transport.

Technological changes that may take place over the planning horizon must also be taken into consideration especially in types and sizes of ships, once this is done, a forecast of the volume of each main class of cargo can be converted by the means of the average ship-load into the number of ship calls.

In Chapter 4 different forecasting methods and techniques will be reviewed such as trend forecasting,scenario writing, gravity models ...etc., their usefulness in developing a model for seaborne trade will be discussed, and finally, the forecasting models will be developed in Chapter 5. It will suffice at this point to give the general background of how to determine future ship calls to a port.

Assuming that seaborne projections are available, a comparison of their volume with the output of the existing berth groups gives a rough picture of the future needs of the berthing capacities and the types needed to cater for the growing volume of traffic, it will also indicate that in addition to expanding present capacity, new types of berths need to be constructed. This rough picture is far from accurate and by itself will most certainly lead to gross over investment or gross under investment when the overall economic optimum for the series of investments is sought.

As was mentioned earlier, if ships arrived with complete regularity and if the time taken to discharge and load ships were constant, the problem will be a simple one, but since ships arrive at a port at random with variable discharge and loading times, the problem becomes much more complex. To refine the rough picture above and draw accurate conclusions, a model representing the arrival of ships to the port, waiting for the tides, and the next shift to start, the times taken to discharge and load the cargo, and again wait for the tides ...etc., and finally depart has to be built in order to determine the waiting times ships spend in port, queue lengths, berth utilisation and idle times ...etc.

Since this is basically a queueing process, the port will be modelled as a multi-berth, multi-queue system. As ships arrive at a port they are admitted to the first vacant berth on a first-come first-served basis. The time interval between arrivals is a stochastic variate with a known probability distribution. The service time for each berth is also a stochastic variate, with each group of berths having its own given probability distribution for service time. When a ship arrives at the port, the tides are checked to determine whether the ships can proceed to the vacant berths, next the hour of the day is checked to determine whether the port is operational or not, then the berths are checked to determine whether any of them is vacant at the moment. If all the berths are occupied, then waiting time occurs and queues start forming until one berth becomes empty, when a berth becomes empty before another ship arrives at the port, idle time occurs until a ship arrives and enters the vacant berth.

In Chapter 4 a discussion of the methods of queueing theory and simulation, their limitations and suitability to model this problem as realistically as possible will be provided and in Chapter 6 details of developing the model will be given.

Once the waiting times ... etc. will be obtained for different vessel types, their waiting costs can be found and compared with the capital cost of berthing facilities and operational and maintenance costs for different time periods, in order to arrive at an optimum investment policy resulting in the least congestion, highest possible berth utilisation and minimal cost. Again different methods of appraisal such as discounted cash flow, net present value using average rate of return, internal rate of return ...etc. will be discussed in Chapter 4 and an investment model will be developed in Chapter 8.

CHAPTER 4

THEORETICAL ANALYSIS AND RESEARCH METHODOLOGIES

4.1 Introduction

Rapid economic expansion in the resource rich developing countries is likely to continue well into the next century and port planning in developing countries is expected to be made on the basis of a continuing climate of growth for the next few decades. The continuing expansion of overseas trade in Iraq implies a continuing expansion of maritime trade, and the extent of berthing capacities required may be several times greater than those existing at present.

While the essence of this study is the consideration of forecasting future levels of seaborne trade, simulating the likely impact on port capacity of the growth in demand and appraising the necessary future investment in new berths, and relies heavily on the interaction of these three key elements, it is necessary to give detailed consideration to each. This will take the following form:-

(i) Outline of the various methods and techniques available
(ii) The strengths and weaknesses of these techniques
(iii) The appropriateness of these techniques in terms of the criteria of this study
(iv) The appropriateness of these techniques in terms of the availability of data.

In order to place this in the proper context, it is necessary to discuss the relevant criteria of port planning both in general terms and specifically for Iraq. It was illustrated in Chapter 3 that the aim of this study is to determine the berthing capacity needed to handle future demand, and since demand is likely to increase with time due to economic and population growth some means of estimating the volume of future demand as accurately as possible is needed, this can be achieved by using one of the many forecasting techniques available such as time series analysis, gravity models, input-output analysis ...etc., which will be discussed in section 4.2. It was also illustrated in Chapter 3 that because of the random arrivals and service times of vessels, some means of modelling the arrivals and departures of vessels in order to determine the waiting times and queue lengths at the port is needed, this can be achieved by using queueing theory or simulation which will be discussed in section 4.3. Finally, in order to determine the optimal strategy of investment in berthing capacity required to meet future demand some means of investment appraisal is required in order to compare waiting costs with capital costs, this can be achieved by using one of the evaluation methods available such as the net present value internal rate of return ...etc., which will be discussed in section 4.4.

4.2 Traffic Forecasting

Any economic action taken today is based on yesterday's plan and tomorrow's expectations, plans for the future cannot be made without some form of forecasting events and the relationship they will have on the future. All planners recognise the importance of forecasting as the basis of rational decisions and actions concerning the future, yet in practice forecasting remains more an art than a science. The essence of port traffic forecasting is to find out:-

(i) What kind and tonnages of commodities will move through the port ?
(ii) How will these commodities be carried as maritime cargo ?
(iii) What ship calls will this result in ?

The first step is to examine the existing traffic in detail on a year-by-year basis. Future ship calls to a port is generated by cargo passing through the port, and the cargo traffic is generated by the production, consumption, population and economic growth. It should, therefore, be possible to determine the dependency between the cargo volume on the one hand and the traffic generation factors on the other.

Whatever the doubts the need for a forecast is there, and the question is not forecast or no forecast, but instead what kind of forecast, bearing in mind that it is impossible to do more than prepare a forecast that is based on the best information available. The value of a forecast is not merely its accuracy but the fact that making it requires a balanced consideration of the factors influencing future development such as economic growth, population growth, production and consumption rates which are the basis for determining the volume of imports and exports.

Seaborne trade is made up of the volume of imports and exports of a number of commodities. Seaborne imports of a particular commodity may represent the total demand of that commodity depending on whether the commodity in question is partly locally produced or totally imported and whether it is imported as seaborne trade, and by other modes of transport also. Seaborne exports on the other hand may represent total supply, again, depending on local consumption and other modes of transport. In addition both imports and exports are influenced by the economic and population growth rates, production and consumption factors. Therefore, in forecasting seaborne trade, the technique chosen should be evaluated in terms of its appropriateness and suitability to predict the total volume of imports and exports in the light of the above mentioned factors, namely, economic and population growth, production and consumption, that is, the criteria of the forecasting technique is its appropriateness and suitability to predict final demand. Other factors that could be included are the number of competing ports in the country.

While forecasting techniques vary from simple expert guesses to complex analysis of mass data, in this section an outline of the relevant forecasting techniques, their strengths and weaknesses together with an evaluation of their appropriateness as they apply to seaborne projections will be provided.

4.2.1 Time Series Analysis

Forecasts are usually based on what has happened in the past, and a promising method of knowing about the past so that inferences can be made for the future is the analysis of time series. A time series may be defined as a collection of readings, belonging to different time periods of some economic variable or composite of variables such as production rate, consumption rate, gross domestic product or population growth rate. A time series then portrays the variation of a variable quantity through time. As such a certain underlying and persistent trend of a series that has continued in the past may be expected to continue in the future.

Therefore, from past data about the volume of imports and exports of commodities, future volumes can be obtained by fitting a trend and projecting for future years by treating the variable quantity of commodities, Y, as a function of time, X, over a period of years.

If Y_t is used to represent the trend values, the trend will be given by the expression:-

$$Y_t = a + bx \qquad 4.1$$

or $$Y_t = a + bx + cx^2 + dx^3 \qquad 4.2$$

... etc., or any other equation representing the shape of the trend.
Where a is the trend when x = o, or the Y intercept
b is the slope of the trend line, or the change in the value of Y_t per unit time.

To fit a straight line trend to a series, all we need to do is to derive the values of the Y intercept and the slope. These can be obtained by different methods, the most commonly used is the least square method (Spur 1967), (Parson 1978), (Hamburg 1970), (Carmel and Polased 1977).

Using the least square method provides us with the most likely forecast, and since forecasting is done under uncertainty, optimistic and pessimistic forecasts can also be obtained by taking two or three standard deviations (σ) above and below the most likely forecast to reduce the uncertainty of the forecast as shown in figure 4.1 below.

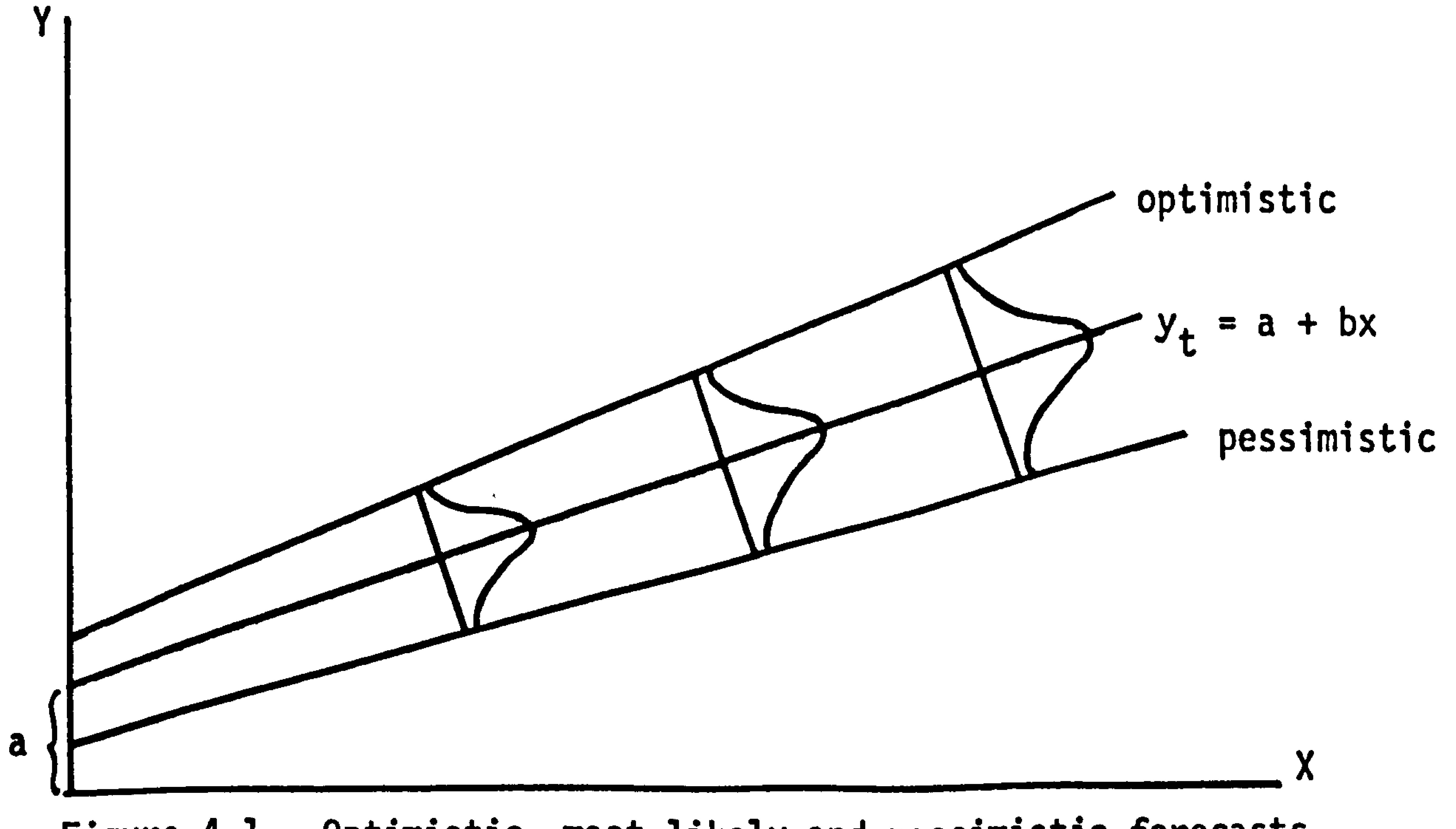


Figure 4.1 Optimistic, most likely and pessimistic forecasts

When a detailed traffic record - for example, monthly figures maintained for several years - is examined, a regular, cyclical pattern may be noticed. This normally results from a seasonal variation in demand for, or production of certain commodities. The continuous trend line can be subtracted from the total to obtain the seasonal variation. There will still be imposed on this seasonal variation a random residual variation as shown in figure 4.2.

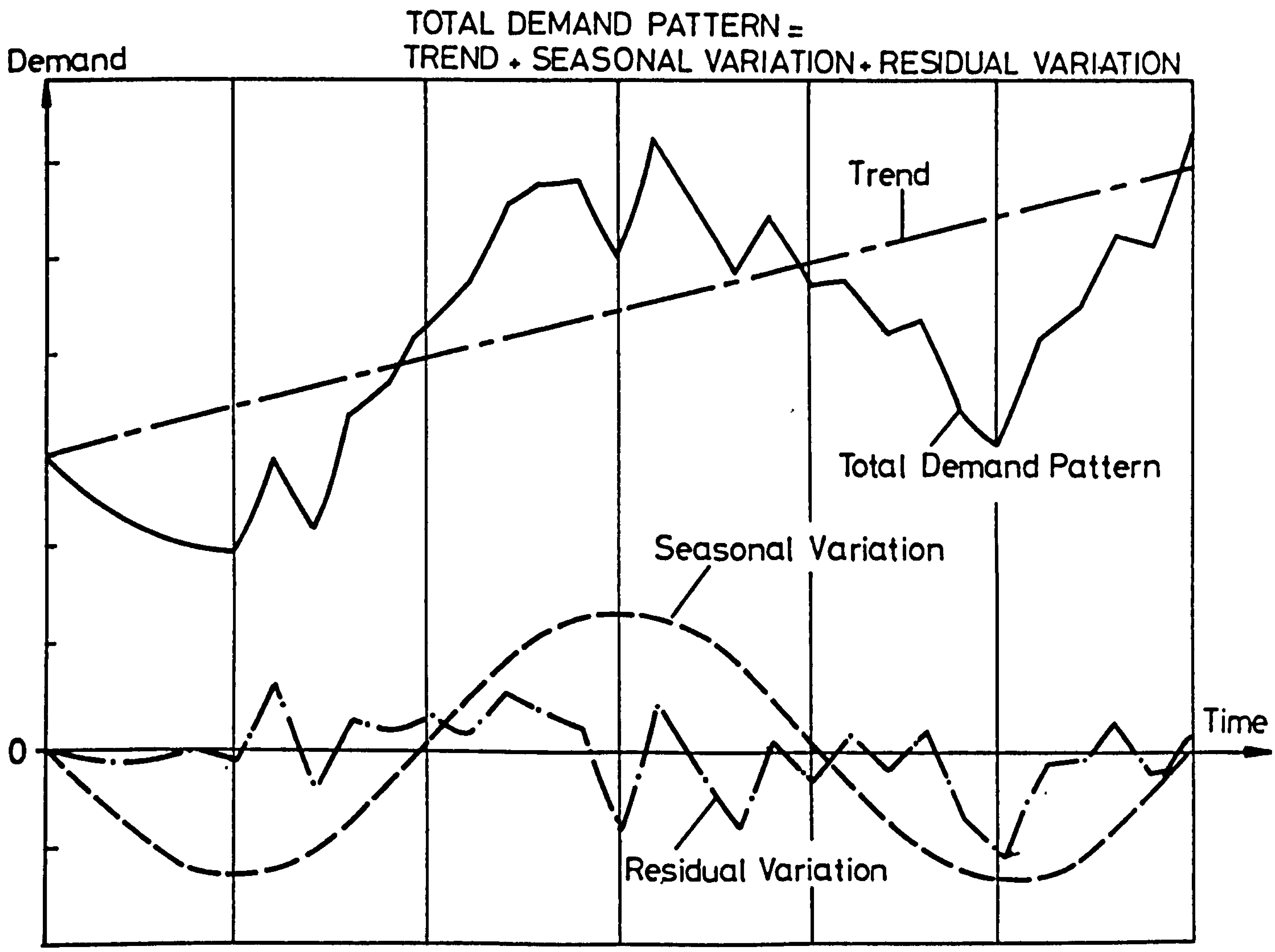


FIGURE 4.2 SEPARATING A SEASONAL VARIATION FROM A TREND

In the previous chapters it was mentioned that trade forecasts should be linked to the economy and economic growth, production and consumption; time series analysis can be used to predict future demand provided past data covering at least the last three years is available and that conditions prevailing in the past will continue into the future, as such time series analysis can be considered as a powerful tool for seaborne traffic projections. Nevertheless time series analysis suffers certain limitation, if the commodity to be imported or exported is new and has no history, or if there is no regular pattern of trend, that is, the import or export figures fluctuate widely, then time series analysis is inappropriate and can be of no help at all. Sometimes traffic in so many commodities could be deliberately developed or run down to satisfy national needs through increasing production rates of certain industries or even manufacture new products that were previously imported hence affecting the volume of imports, again if this is the case, then the use of time series analysis cannot be relied upon to produce accurate future estimates of demand since this implies the fact that over the last few years a particular class of traffic has been increasing does not necessarily mean that the trend will continue into the future.

4.2.2 Scenario Writing

A traffic scenario is a consistent description of the whole of the future traffic likely to come to the port. It assumes that the port has done nothing to prevent the traffic arriving but has encouraged it by providing reasonable facilities. The idea is to get a picture of which different directions the traffic may develop and, therefore, scenarios are worked out independently by several parties representing different interests in the port development such as shippers, ship owners, port managers and representatives of different planning authorities all using as much as possible of knowledge about the past development, sound judgement and imagination.

For each class of cargo category the probable volumes under different circumstances and possible alternative types that may be used in carriage and handling are considered. Several scenarios are then prepared after the analysis of traffic data, examination of numerical trends and simple projections have been made which are the data on which the scenario is based.

Long term scenarios can be worked independently (Gulbradsen 1973) according to the following dispositions:-

(i) World trade level
(ii) National trade level
(iii) National trade modes (volume in each mode, major trades)
(iv) Classes of cargo via port (volume of each class)
(v) Classes of ships using the port (size, average cargo carried)
(vi) Port operating policies
(vii) Cargo handling technology for each class of cargo (average tons per hour)

Since scenario writing involves several parties representing different interests in port development and is based on the analysis of traffic data and trend projections, it overcomes the difficulties faced by time series analysis, for example changes in trends or the introduction of a new commodity are incorporated and analysed in scenario writing. Hence it is a very useful technique for seaborne projections and is considered to be the most important forecasting technique in strategic planning (Fahey, King and Narayanan 1981).

4.2.3 Gravity Models

The gravity model relates traffic to generation and resistence factors. The traffic resistance factor may be measured by the distance of a pair of geographical areas which transits their traffic through the port, other measures are the cost or time of transportation from one area to another. A simplified example of such a model (Carrothers 1956) when traffic generation data are available for the origin and destination area, is

$$T_{ij} = K_{ij}(P_i P_j) \qquad 4.3$$

where T_{ij} is the traffic between area i and j through the port

P_i and P_j are the traffic generation factors, for example production volumes in area i and j, respectively.

K_{ij} is a resistance factor

when T_{ij}, P_i and P_j are observed, the factor K_{ij} may be determined.

The model works in the following way; if the generation factor in one of the areas increases by 10 percent the traffic is also assumed to increase with the same percentage. The value of K_{ij} should be determined for each pair of areas and also for each type of flow through the port.

If origin-destination observations are available for two different points of time (two different years) the influence of change in technology and economy on the generativity of traffic generation factors may be taken into account. The factor K_{ij} may in this case be assumed to vary linearly with time.

$$K_{ij} = a_{ij}t + b_{ij} \tag{4.4}$$

where t is the year in which the observation was made

a and b are constant

using expression 4.4 in 4.3 we get

$$T_{ij} = (a_{ij}.t + b_{ij})(P_iP_j) \tag{4.5}$$

with two sets of observation of T_{ij}, P_i and P_j the constants a_{ij} and b_{ij} can be determined for each pair of areas i and j.

A variety of models can be applied in traffic forecasting dependent on the specific problem involved and the available data.

It was mentioned in section 4.2 of this study that the number of competing ports in the country constitute a criteria of appropriateness in choosing a forecasting technique, therefore, in a country where there are many competing ports and where traffic data could be split on hinterland areas accurately, gravity models become a useful forecasting tool especially when the aim is to minimise transportation costs.

4.2.4 Input - Output Models

In input-output analysis, the economy is broken down into sectors or industries and the flow of goods among sectors or industries is registered to indicate the relations amongst them. These relations tell us what inputs are required from various segments of an economy to produce a given output in one sector of that economy (Burgess 1968).

The output of an industry may be sold to other industries as an intermediate input or sales to final customers as a final demand. This may be expressed for n sectors as:-

$$X_1 - X_{11} - X_{12} - X_{13} - \ldots X_{1n} = Y_1 \qquad 4.6$$

where X = gross output

X_{ij} = inter-industry sales

and Y = final demand

For each sector in the economy there will be an equation like 4.6. If the amount of industry 1's output bought by each purchasing industry (1, 2, -----, n) is a linear function of the latter's output (Richardson 1978), equation 4.6 becomes:-

$$X_1 - a_{11} X_1 - a_{12} X_2 - a_{13} X_3 - \ldots a_{1n} X_n = Y_1 \qquad 4.7$$

where $a_{11} = X_{11}/X_1$,-------$a_{1n} = X_{1n}/X_n$. The a_{ij}'s are called technical coefficients and they represent the direct requirements of the output of any sector i per unit of output of any other purchasing sector j. The set of n linear equations like 4.7 above provides a simple and useful way of describing the interaction of final demands, the input requirements of each industry and their gross outputs. The input coefficient matric $A(\sum_i \sum_j a_{ij})$ which is obtained from the n equations each like 4.7 enables us to determine the effects of specified changes in final demand upon gross output. In matrix form the equations are:-

$$X - AX = Y \qquad 4.8$$

where X and Y are column vectors of gross output and final demand respectively.

The application of input-output techniques requires the preparation of an input-output table for the economy being studied. With such tables it is possible to predict the demand that will be imposed on any industry (Chiou-Shuang Yan 1969).

Making an input-output analysis is a complex procedure, it requires the collection of the data needed for the basic table summarising the origin of all various inputs and the destination of all various outputs of all industries pertaining to a country's economy which is a very difficult task and large scale models include thousands of possible cross-classifications. Accurate determination of the technical coefficients require incredible amounts of statistical data and since the coefficients are based on past relationships, and changes in the way the economy operates will not be reflected unless the coefficients are updated.

The most serious limitation in using input-output models is the fact that separate forecasting techniques are needed to predict changes in final demand (Richardson 1978), yet input-output models are valuable tools for prediction and forecasting, they are used in market and centrally planned economies alike. They permit an evaluation of the output, income and employment repercussions of exogenous changes in final demand, including the expansion of existing industries, the entry of a new plant or changes in the level of government spending.

Hence input-output models are very useful for seaborne forecasting, they are used by the British Port Authority in forecasting port traffic and were used by Professor W Leontief to estimate the growth of maritime traffic up to the end of this century.

To conclude this section, all that can be said about the appropriateness of the aforementioned forecasting techniques is that they can all be used for seaborne projections and it is very difficult to say that one technique is superior to the other, since this depends on the specific problem involved and the available data. Input-output models are probably the most advanced form of forecasting when compared to time series analysis and scenario writing, while the use of gravity models might be preferred when the aim of the study is to minimise transportation costs between the origins and destinations provided that there are many competing ports in the country. Since this study is concerned with Iraqi ports, the appropriateness of the forecasting technique to predict Iraqi seaborne projections will be discussed in section 4.5.

4.3 Queueing Theory and Simulation

Ships arrive at the port from different origins and depart to different destinations via different routes to unload/load cargo of different types at different berths. This is essentially a queueing process. Queues or waiting lines of ships form if the berths available to serve the ships are occupied and ships have to wait their turn to be served. It was mentioned in Chapter 1 of this study that most studies of port investment fall into two categories, the theoretical studies from which conclusions are usually derived from considerations of analytical models such as queueing theory, and the case studies which are derived from data collected in particular ports, in the latter case if analytical techniques cannot be used then numerical ones such as simulation will be used. The difference between the simulated and theoretical techniques is that the basic idea of simulation is to simulate the system in a computer using actual data collected from operational statistics of a particular port, whereas the theoretical technique is concerned with building a model of the system which seems to answer certain questions as regards the system operations in general sense by substituting several simplifications in place of the complicated reality.

The essence of this study is to develop a queueing model (analytical or numerical) in order to obtain the waiting times of ships and their distribution, idle times of berths and their distribution and finally queue lengths of ships and their distribution. In developing a model for the probability distribution of waiting times ... etc., certain assumptions must be made about features pertinent to the formation of a queue.

1. The manner in which ships arrive and become part of the queue.
2. The number of berths (service units) operating on the ships requiring service and the service policy, e.g. limitations on the amount of service that can be rendered or is allowed.

3. The order in which ships are serviced; the queue discipline.
4. The service provided and its duration, the service output.

In such situations problems arise because of either too much demand on the facilities, in which case either there is an excess of waiting time or there are not enough service facilities, or too little demand in which case there is too much idle facility time or too many facilities. One would like to obtain an optimum balance between the costs associated with the idle time and waiting time. Both queueing theory and simulation can be used to determine the waiting time, idle times ...etc., and depending on the specific problem involved it can be decided which technique to use. When models defy mathematical solution or even when the level of mathematics required becomes involved and complex, simulation is usually used, otherwise queueing theory is used. Hence the criteria to use either of the techniques is the mathematical complexity of the model required to represent reality as closely as possible, that is whether an analytical solution is possible or not. In this section an outline of both techniques, their strengths and weaknesses together with an evaluation of their approriateness as they apply to modelling and solving different port queueing problems will be provided.

4.3.1 Queueing Theory

In queueing theory, a system can be described by its input or arrival process, its queue discipline and its service mechanism. The usual description of the pattern of arrivals is given by the probability distribution of time between successive arrivals and the number of units that appear at each of these events. Often, successive interarrival times are infact statistically independent, but of course they need not be in a a particular situation. Usually the arrivals are assumed to occur at random and that the probability of an arrival at any time remains constant. Under these assumptions, the arrivals would obey the Poisson probability law, being a Poisson variable, the mean arrival rate, or the average number of arrivals per unit of time is λ which is independent of time, the reciprocal $1/\lambda$, is the mean length of time intervals between two successive arrivals. In other words we have a Poisson arrival pattern and an exponential pattern of interarrival time.

The queue discipline, which is the established rule by which customers waiting in the line are served, describes the order in which the ships entering the system are eventually serviced. Frequently, the discipline is first-come-first-served. Sometimes the service order is last-come-first-served, or the discipline is governed by a priority rule.

In common with the arrival process, a specification of the service mechanism includes a description of time to complete a service. The time needed for service partly depends on the customer's requirements, but it also depends on the state of the system (that is, how congested it is), for example, the servers may hurry if many customers are waiting. Likewise, for each service facility, successive service times may, but need not, be described independently and identically distributed random variables. The service mechanism also prescribes the number and configuration of servers and channels. When the servicing time is exponentially distributed, the mean service rate, or expected number of services performed per unit of time and the standard deviation of servicing times are identical and may be denoted by μ, the reciprocal $1/\mu$ is the mean servicing time, or the expected time per service.

When the above conditions are satisfied, it is possible to proceed with the mathematical formulation of the model. In order to know whether the servers can handle the customers, we must compare λ with μ, when $\lambda \geqslant \mu$ the queue will grow indefinitely and we must, therefore, have $\lambda < \mu$ or $\lambda/\mu < 1$ for a single server and $\lambda/k\mu < 1$ for k identical server channels.
The ratio

$$U = \frac{\lambda}{\mu} \qquad 4.9$$

is called the utilisation parameter, since it measures the degree of the capacity of the service station that is utilised. For a single server station, if U is the proportion of time that the server station is kept busy, then the proportion of time the server station is kept idle must be

$$I = P_0 = 1 - U \qquad 4.10$$

As I, the percentage of time the server station remains idle, it is also the probability that a customer, upon his random arrival, will not have to wait at all for service. This probability is denoted as P_0 in 4.10. The various expected values of interest that can be obtained from solving queueing problem can be determined as follows:-

1. The mean number of customers in the system

$$E_n = \frac{\lambda/\mu}{1 - \lambda/\mu} = \frac{\lambda}{\mu-\lambda} \qquad 4.11$$

2. The mean length of the waiting line

$$E(L) = \frac{\lambda}{\mu}\left(\frac{\lambda}{\mu-\lambda}\right) = \frac{\lambda^2}{\mu(\mu-\lambda)} \qquad 4.12$$

3. The average waiting time of an arrival in the queue

$$E(W) = \frac{\lambda}{\mu(\mu-\lambda)} \qquad 4.13$$

4. The average time an arrival spends in the system

$$E(T) = \frac{1}{\mu-\lambda} \qquad 4.14$$

Similar equations are derived for multiple service-station queueing models (Morse 1963), (Lee 1965), (Page 1972) and (Newell 1982). With these basic six equations, many questions concerning waiting times of ships in port can be answered and solutions obtained, as was explained in Chapter 1 of this study concerning the article of Jan de Weille and A Ray.

Most of the literature on modelling the arrival and departure of ships at a port makes extensive use of queueing theory, it is not difficult to see why since the techniques of queueing theory are so well developed and the literature on this topic is plenty. This implies that queueing theory is a powerful tool for modelling port problems as long as the problem yields itself to mathematical solution. In queueing theory the probabilities of arrivals within various time periods and the probabilities of various service times are analysed theoretically to yield precise mathematical formulae giving the probabilities of having to queue for any specified time to be served. Similar formulae have been developed for several combinations of different types of arrival and service time patterns. What makes the use of queueing theory so attractive is that not only the formulae are relatively easy to use but most have been prepared in the form of graphs showing the relationship between congestion and berth occupancies and the relationship between annual port capacity, congestion and berth occupancies (Noritake and Kimaru 1983).

All the studies making use of queueing theory techniques usually assume that arrival times are random following a Poisson distribution, and service times are random following a negative exponential distribution. This is one of the limitations and weaknesses of queueing theory. Because of the complexity involved, only the relatively simple type of systems could be analysed theoretically, (Ackoff 1968) states that - "Unless we assume exponentially distributed service time, however, or some extension thereof, the mathematics rapidly become relatively complex. Because of the mathematical simplicity that exponential service times yield, they have been studied extensively ...... The theory is so complicated if other assumptions are made. It may become so complex that we must resort to simulation to learn what we want to know of the process."

The other weakness of queueing theory is when arrival and service time distributions cannot be approximated to fit any of the theoretical distributions and can only be represented by empirical distributions, hence prohibiting the use of queueing theory. In addition to the above mentioned limitations, the constraints of some problems do not lend themselves to analytical solution, for example if the ports are tidal, the tide's constraints cannot be incorporated into the queueing theory model; or if the service times of berths is not equal, that is the service channels are not identical and have different distributions of service times.

4.3.2 Simulation

Given a mathematical model of the system, it is sometimes possible to derive information about the system by analytical means as in the case of queueing theory. Where this is not possible, it is necessary to use the numerical computation methods for solving the equations. It was mentioned in Chapter 1 of this study that changing the physical capacity of the port to meet present and future requirements is a dynamic process, and in dynamic mathematical modelling a technique identified as systems simulation is one in which all equations of the model are solved simultaneously with steadily increasing value of time. Systems simulation is a technique for modelling a complex process which would otherwise defy analytical solution, because of the stochastic behaviour and non-linear characteristics of the process, and solves problems by following the changes of a dynamic model of the system.

(Naylor 1968) gives the following definition of simulation "Simulation is a numerical technique for conducting experiments on a digital computer, which involves certain types of mathematical and logical models that describes the behaviour of business or economic system (or some component thereof) over extended periods of time."

Since the technique of simulation does not attempt to solve the equations analytically, a mathematical model constructed for simulation purposes is usually of a different nature than the one constructed for analytical techniques. When building a model for analytical solution, it is necessary to bear in mind the constraints set by the analytical technique and to avoid complicating the overall model. Many gross assumptions may have to be made such as ignoring the tidal constraints, assuming that arrivals are mainly of homogeneous commodities and service rates of all different types of berths are equal....etc. A simulation model however, can be constructed more freely ,taking into consideration the constraints of shifts, tides, different service times of berths and giving full details as to what happens to each ship from the time it enters the system to the time it leaves.

Typically a simulation model is built in series of sections, each can be described mathematically without undue concern for the complexity introduced by having many such sections. The equations, however, must be constructed and organised in a way that enables a routine procedure to be used for solving them simultaneously. In the case of ports where the system is discrete, the prime interest is in the events, the equation are essentially logical stating the conditions for an event to occur. The simulation consists of following changes in the state of the system that result from the succession of events. It is possible to advance time in small increments and check at each step if any events are due to be executed. As a general rule, however, discrete simulation is carried out by deciding upon the sequence of events and advancing time to the next most imminent event.

Unlike queueing theory there is no unifying theory of digital simulation although there are some good books on the subject matter which are very useful (Naylor 1968), (Fishman 1973), (Rubenstein 1981) and (Tocher 1973); but none has any mention of port planning. Therefore, an account of the analysis of the port system for the purpose of writing a computer programme which simulates that system will be provided. First we must identify the mathematical and the logical components of the system. The mathematical components can be classified under the following headings:

i) <u>Exogenous Variables</u>

These are the variables imposed on the system from outside and to which the system must respond correctly. In terms of a computer programme they are generally those variables whose values are obtained by sampling from frequency distributions; such as inter-arrival times, service times, operation times, and the yearly or daily demand.

ii) <u>Parameters</u>

The computer programme may describe the system in general terms and by assigning specific values to the parameters the particular system will be obtained such as the means and variances of the frequency distributions which provide the exogenous variables, parameters describing the initial conditions, length of the simulation run, and parameters describing the operating rules.

iii) <u>Status Variables</u>

The status variables describe at any moment in simulated time the state of the system, such as simulated time span, queue sizes, waiting times of arrivals, total waiting time, and total idle times of facilities.

iv) <u>Endogenous Variables</u>

These are the variables generated by the simulation programme and in general they are the variables which one wants to evaluate such as average waiting time of arrivals and average waiting time of facilities.

v) Operating Characteristics

Generally these are the types of distributions which provide the exogenous variables. In simulation it is possible to use theoretical distributions and emperical distributions that are found from past data.

vi) Identities

These are the mathematical formulae which appear in the system, and which describe the relationships between the various variables.

The logical components of the systems are:

i) Entities

These are the components of the system which for the purpose of simulation are considered indivisable such as ships and berths.

ii) Sets

These are groups of entities which are in an identical state such as ships in harbour, queues of ships waiting to enter the berths and berths which are idle.

iii) Events

These are moments in simulated time when the state of the system changes such as beginning of service, computation of service time....etc.

Having identified the mathematical and logical components of the system, it becomes possible to formulate the problem and write the computer programme for it.

To conclude this section, both queueing theory and simulation modelling are both very useful in planning and studying port systems. The main features of the two techniques may be summarised as below.

Although queueing theory is very quick and easy to use, it is severely limited in the complexity of the systems which it can represent and, therefore, of the problems to which it can realistically be applied.

Simulation can overcome many of the problems inherent in queueing theory techniques but is very time consuming and costly in initial program preparation (Guise 1982). Hence, depending on the specific problem involved queueing theory can be used in the following conditions:-

(a) Arrival and service time distributions can be represented by theoretical distributions.

(b) There is no interest in the first few arrivals of ships, and the interest lies in the steady state condition (that is when the process reaches stability), this implies that the same service rates of service are maintained throughout irrespective of the degree of congestion in the port. In other words, it means that demand is inelastic and arrival and service times are not dependent on the pressure of the system.

(c) Arrivals are mainly of homogeneous commodity and service rates of all different berths are equal, that is, ship types and sizes are assumed to be similar and berths interchangeable.

(d) The overall model lends itself to analytical solution. Problems possessing the above characteristics exist in most of the single purpose ports such as oil terminals and grain terminals, but they are few in reality since most of the ports all over the world are multipurpose ports catering for a multitude of different commodities.

If, on the other hand, one is faced with the more complex interactions, such as are often of importance in the realistic representation of complex multi-purpose ports and where reality cannot be solved analytically, then simulation must be used as in the following conditions:-

(a) Interest lies in the steady state condition (when the process reaches stability), the nonsteady state (e.g. when a service facility is only open for a short time), or the transient state (e.g. when there is sudden demand such as in the opening of a department store on the day of a big sale).

(b) Arrival and service times can be represented by empirical as well as theoretical distributions.

(c) Berths are not interchangeable, and even if they are, service times are different for different ship types and sizes.

(d) Ports are tidal and operate at specific hours of the day.

In brief if we are dealing with multipurpose, tidal ports with different service rate of non interchangeable berths then simulation would be preferred to queueing theory, while the use of queueing theory to single purpose ports is very useful.

The value of simulation arises because it can rapidly give useful information about the dynamic behaviour of the real system that the model represents, it is also more flexible and, therefore, more valuable in complex situations in that it has the advantage of enabling additions to be made to the basic programme to take account of the additional factors as they arise and may eventually be the only satisfactory way of representing all the relevant port operations.

However, simulation models require a great deal more detailed input data than queueing theory, but consequently provide more detailed output and greater insight into the causative factors related to port operations. The complexity and interactions involved would probably make the simulation model prohibitively expensive and time consuming especially in initial programme preparation. Certain other difficulties arise with simulation, for example, it is not easy to tell when the steady-state in simulating the system has been reached since simulation starts in an empty state and does not immediately represent a state of equilibrium, so the model should allow for a specification of a time period (called run-in-time) to allow the process to reach stability during which no performance of statistics are collected; and finally parallel runs of the same time period are sometimes needed to determine the variations and establish what effect variations in traffic volumes are likely to have on port investment programmes.

4.4 Investment Appraisal

The final and most important phase of port planning is investment appraisal, having obtained the relevant output of simulation, most important of which is the waiting time of ships at ports which describes the degree of congestion and costs many millions in chronic cases. On the light of this information investments in berthing facitities are undertaken to allow the efficient flow of goods in and out of the country and to reduce the congestion costs of ships and cargo on board. Investment in berthing facilities involves investments amounting to approximately 8 million Iraqi dinars for a general cargo berth and much higher for a container berth, arising from construction costs of berths, sheds, warehouses, cranes and the operation and maintenance costs of these facilities. On the other hand they generate a stream of benefits through easing congestion and hence improving the overall turn-around time and thereby reducing ship's waiting time costs.

In order to evaluate the above costs (construction costs) and benefits (relieving congestion) of the project, it is necessary to compare these costs and benefits to see if it is worthwhile to carry out the project. Since port investment problems are dynamic in nature and cover planning horizon of few decades, the costs and benefits of a project occur at different time periods of time and are not directly comparable. Hence a discounting technique should be adopted so that future costs and benefits arising from the investment can be compared and the net present value obtained. If the net present value of the investment is positive, then the project is worthwhile and should be made. This leads to the first criterion in appraising projects of a dynamic nature, namely, the discounting criterion that enables future costs and benefits to be compared.

While it is possible to obtain the costs of investment on a year by year basis, it is very difficult to obtain the benefits derived from reducing congestion through new investment when the traffic volume is increasing continuously (otherwise if the traffic volume is not increasing, a one-off investment is sufficient). This requires the simulation of the increasing volume of traffic for different numbers of berth confirgurations on a year by year basis in order to determine the waiting time costs of ships. When planning for twenty years ahead, a year by year simulation becomes very time consuming and very costly since it requires the simulation of 20 separate years for a different number of berth additions for different cargo classes, different forecasts (optimistic and pessimistic in addition to the most likely) and for different operating policies (operating hours and shifts). Thousands of simulations will be required taking months probably years to obtain the required data. This leads to the second criterion for appraisal, that is an optimum investment strategy should be developed whereby conclusions about future investment in berthing facilities can be drawn, from a reasonable number of simulations taking place every five years thereby reducing the work by 75 percent.

In what follows a brief outline about discounting will be provided because of its importance in problems of this kind. A pound today is worth more than a pound a year hence, a pound put in a bank will grow at i percent (the interest rate) to 1 + i pounds in a years time. By similar reasoning, a benefit now is preferred to the same benefit later. This explains the existence and necessity of a discount rate which allows the comparison of costs and benefits occurring at different time periods to be made. The present value of a pound received n years from now can be looked up in present value tables which is nothing more than a bond yield table that takes account of compound interest. To illustrate the process of discounting, consider the following example. A project costs £10 million and takes one year to build. It gives net benefits of £3 million for each year of the project life of five years. Costs and benefits are assumed for simplicity to occur at the end of the year and a discount value of 10 percent is used. If benefits are assumed to start from year one, the net present value of the project is £1.373 million as shown in Table 4.1 below

Year	Cost £million	Net Benefit £million	Discount Factor[(a)]	Present Value £million
0	- 10		1.000	-10.000
1		3	0.909	2.727
2		3	0.827	2.481
3		3	0.751	2.253
4		3	0.683	2.049
5		3	0.621	1.863
				1.373

TABLE 4.1 CALCULATION OF NET PRESENT VALUE OF PROJECT

(a) Obtained from present-value tables.

For a constant stream of benefits such as this, the formula of the present value of annuity can be used:

$$P_n = \frac{1}{r}\left[1 - \frac{1}{(1+r)^n}\right] \qquad 4.15$$

$$P_n = \frac{1}{0.1}\left[1 - \frac{1}{(1+0.1)^5}\right] = 3.791$$

Thus the discounted benefits amount to £3 million x 3.791 = £11.373 million

If from this figure the discounted costs of £10 million are subtracted, the result is the same £1.373 million.

What discount rate to use in project evaluation is sometimes an important matter. To see the importance of the choice of a discount rate and its effect in project evaluation it is useful to examine its role relative to the net present value. The relationship is thus that the net present value decreases as discount rate increases as the former is an inverse function of the latter. Continuing with the above mentioned example and using different discount rates, the following results are obtained:-

Discount rate %	5	8	10	15	18
Net Present Value £millions	2.843	1.832	1.373	0.049	-0.524

The project becomes unacceptable for discount rates slightly higher than 15 percent, hence depending on the choice of discount rates the project might be accepted or rejected, obviously the lower the discount rate chosen the more justifiable the project is and vice versa. This gives rise to the possibility of tampering with discount rates to justify projects and hence discount rates should be chosen with care. As far as the port authority is concerned, the discount rate to be used in its project evaluation should be the opportunity cost of capital which is the (minimum acceptable) rate of return that the port can earn with the capital in an alternative use. It will be assumed that the discount rate is a known element being specified by the national government and 8 percent is used in Iraq.

In what follows an outline of the relevant evaluation methods as they apply to port investment such as the average rate of return, payback method, net present value, benefit cost ratio and internal rate of return (Merrett and Sykes 1971); their strengths, weaknesses together with an evaluation of their appropriateness as they apply to port investment problems will be provided.

4.4.1 Average Rate of Return

The average rate of return is an accounting device and represents the ratio of the average annual profits to the average net investment in the project or the original investment itself.

The main advantage of this method is its simplicity. It makes use of accounting information already available in the accounts. Having obtained the average rate of return, it may be compared with the required rate of return to determine whether the investment should be carried out or not. The major disadvantages of this method are that it is based upon accounting income rather than upon cash flow and it fails to consider the timing of cash inflows and outflows. The time value of money is completely ignored; the benefits in the last year are considered equal to those which accrued in the first year. Thus the average rate of return method can not be used for projects which have different pattern of time streams of cash inflows and outflows.

4.4.2 The Pay-back Method

The pay-back method means the number of years required to recover or pay-back the initial investments. It is the ratio of the initial investment over the annual net cash inflows for the pay back period.

The main disadvantages of this method is that it ignores cash flows after the pay-back period in addition to its short coming of not taking into account the magnitude and timing of cash flows during the pay-back period and the time value of money.

4.4.3 The Net Present Value Method (NPV)

This method overcomes the shortcomings encountered in the average rate of return and the pay-back method by first taking into account the time value of money and thus the importance of the timing of the cash flows. To use the NPV, the discount rate i has to be specified. For each different discount rate a different net present value would be obtained. The criterion used in the NPV method is to accept the project if the NPV is greater than zero and to reject it otherwise. Using this method provides an objective basis for evaluating and selecting investment projects. The discounting process takes into account both the magnitude and timing of expected cash flows in each period of the whole life of the project.

4.4.4 Benefit/Cost Ratio

The benefit cost ratio uses the present value of benefits (PV(B)) and the present value of costs (PV(C)), but instead of subtracting one from the other to obtain the NPV, the benefit/cost ratio is obtained by dividing one by the other as follows:-

$$\text{Benefit/cost ratio} = \frac{\text{Present value of benefits}}{\text{Present value of costs}}$$

Thus a positive NPV implying that a project is acceptable, corresponds to a benefit/cost ratio greater than one, whereas a negative NPV implying that a project is unacceptable, corresponds to a benefit/cost ratio of less than one.

4.4.5 The Internal Rate of Return (IRR) Method

This is another method which involves discounting. The IRR is the highest discount rate that will give a positive NPV. In other words, it is that discount rate which will make this NPV of the project zero, i.e. such that present value of benefits equals present value of costs, it is the value of i that will make PV(B) - PB(C) = 0.

If the IRR of a project exceeds the required rate of return, the project is acceptable and if not, it is rejected. In general, the IRR and the NPV method will give similar answers to the acceptance and rejection of an investment proposal.

From the brief outline of the five techniques above, it becomes clear that the average rate of return and pay back methods are not suitable in evaluating port projects since they do not use any form of discounting and the use of the other techniques is more appropriate.

In ports, since the investment is frequently made against a background of congestion and long waiting time for ships, the addition of one or more berths can reduce ships' queueing time for a berth from a high level, resulting in a substantial reduction of ships waiting time cost. This cost reduction taken as a benefit of the additional berth will consequently generate a very high IRR, if a second additional berth were also constructed, the marginal reduction of ships'waiting time would be much less than the reduction affected by the first additional berth as will be seen in Chapter 7, consequently the IRR calculated for the second additional berth would be smaller than that for the first additional berth and may infact be negative. Furthermore, if two or more additional berths were taken jointly as one investment, the IRR, when determined, will be less than that for the one additional berth alone. This suggests that the appropriate level of port investment will often not be that which gives the highest IRR. When the IRR obtained is high by comparison with the required rate of return, it only indicates that the proposal under consideration is acceptable and no sound comparisons in such a case can be drawn between alternative levels of investment.

In other words, the very nature of investment to relieve or prevent congestion means that the first additional capacity will look a better investment than the second and subsequent ones, since it can count as benefits a very large reduction in congestion costs which subsequent capacity increases cannot possibly match and hence this must not be used as an argument that this first, limited, investment is the most economic since in the long run this would amount to the planning for a permanent and substantial level of congestion.

Therefore, in deciding what is the right number of berths to invest in at any time, it is better in view of the possible high congestion cost distortion to work where possible with NPV rather than IRR.

If the total cost of ships' waiting time per annum in a port is for example £3 million now, and after investing in new berths, provided there is no traffic growth, this cost becomes £1 million, the cost saving is £2 million. With a growth in traffic volume using the port, the total cost of ships' waiting time might increase to say £6 million thus with new investment, the cost saving benefit will be of £5 million and, therefore, the benefits derived from reducing congestion should be made on a dynamic basis. This unfortunately creates problems in port investment appraisal since ports should normally plan on the basis of a continuing climate of growth.

As mentioned earlier in this section, while it is possible to obtain the costs of investment on a year by year basis, it is very difficult to obtain the benefits derived from reducing congestion through new investments when the traffic volume is increasing, requiring many simulations. In addition to what has been said above it is sometimes impossible to find the waiting time costs accurately if the traffic demand exceeds the supply of facilities, that is when the traffic utilisation factor λ/μ exceeds one and the system becones unstable, therefore, requiring more simulations of the stable system by increasing the number of berths.

This is why most of the literature on port investment attempts to find the optimum number of berths required at 4 or 5 years intervals or compare different investment alternatives (strategies) already proposed by the country or the consultants doing the work. Those alternatives are evaluated separately and the cheapest is recommended. For example, the available alternatives for container berths might be the following:-

Alternative A	Build 6 berths in 1985
	" 4 berths in 1990
	" 9 berths in 1995
	" 2 berths in 2000
Alternative B	Build 10 berths in 1985
	" 2 berths in 1990
	" 6 berths in 1995
	" 6 berths in 2000
Alternative C	Build 5 berths in 1985
	" 5 berths in 1990
	" 5 berths in 1995
	" 5 berths in 2000

Simulating the above alternatives, the costs and benefits of each alternative can be obtained and hence its net present value can be worked out and the alternative with the highest net present value is recommended.

Unfortunately, neither of the two methods discussed above is good enough to arrive at an optimum investment policy. A year by year simulation and evaluation is very cumbersome in addition to being very costly and time consuming, and the choice from already given alternatives might be far from the overall optimum if better strategies were available or could be worked out, plus the fact that additions in berthing capacities need to be made in between the 4 or 5 years if demand is increasing rapidly.

While the use of the NPV satisfies the first criterion of evaluating port appraisal problem there is no way to satisfy the second criterion and hence a new model should be developed to overcome this difficulty.

4.5 Research Strategy

In the previous sections, it was mentioned that port planning is dependent on forecasting future demand (seaborne trade) and the number of ship types calling at the port; modelling the arrival and departure of ships as a queueing process as realistically as possible and finally appraising the costs and benefits of a project to arrive at an optimum investment policy in berthing facilities at any future time period. From the foregoing discussions of the different forecasting techniques, queueing theory and simulation; and investment appraisal, it is possible to give a summary of the criteria for the three key elements above, in other words, what is required from those methods for port planning problems, so that an evaluation can be made leading to the selection of the most appropriate method.

4.5.1 Summary of Criteria

As far as forecasting is concerned the methods or techniques to be used should satisfy the following criteria:

1. It should be possible to forecast seaborne trade for at least 5-20 years ahead.

2. Seaborne trade forecasts should be determined by forecasts of each sector in the economy or past data of maritime transport.

3. The commodity forecasts for all sectors should be linked in a manner consistent with the mode of carriage, that is, they should be linked to a modal split model to forecast the seaborne trade; and to the way they will be carried as maritime cargo.

4. The independent variables of the forecasting model themselves such as consumption, production, gross domestic product and population should be relatively easy to forecast for long time periods ahead to satisfy the first criterion.

In order to choose between queueing theory and simulation, the following criteria should be satisfied:

1. The queueing model should be capable of dealing with random arrivals of ships and random service times of berths fitting any of the theoretical or emperical distribution.

2. Should be capable of predicting the waiting times of different ship types, idle times of different berth types and queue lengths of ships for different types of berths.

3. Should be able to accommodate discontinuities such as shift times and tidal times.

4. Capable of dealing with multi-purpose ports with different commodities and different berth types.

5. Capable of dealing with berths shared by different cargo and ship types.

Finally for the investment appraisal the methods chosen should satisfy the following criteria:

1. Take into account the time value of money and the timing of cash flows.

2. Take into account the congestion cost distortion discussed on page 79.

3. Capable of determining the benefits derived from reducing congestion through new investment when the traffic volume is increasing.

In the next section a brief evaluation of the methods against the above stated criteria will be provided.

4.5.2 Evaluation of Methods

Ideally speaking when all the data required for forecasting is available and there is no restriction regarding the length of time the forecast may take all the aforementioned techniques, that is, time series analysis, scenario writing (which is partly dependent on time series analysis for trend projections), gravity models and input-output models satisfy the first and second criteria. They can be used to forecast seaborne trade for each sector in the economy for 5-20 years ahead.

As far as criteria 3 is concerned time series analysis and input-output models cannot be used to predict the mode of carriage (i.e. mode of transport such as air, sea or land). Scenario writing can be used in this instant both to predict the mode of carriage and the way the commodities will be carried as maritime cargo. In case there is competition between different ports in the country such as some ports are nearer than others to the consumption and production centres, or the modes of transport in the country are in direct competition, for example, there might be an airport near the consumption centres where high value commodities can be transported by air, or even good highway or rail routes linking neighbouring countries to such centres, then the gravity model becomes most useful.

Finally, the fourth criterion which is best obtained from the country's economic plans and past trends, is satisfied both by time series analysis and input-output models although predicting changes in final demand requires the use of separate forecasting techniques since final demand is an exogenous variable in input-output analysis as discussed in the model in section 4.2.4.

In brief, there is no easy way to say that one forecasting technique is superior to another since each technique has certain advantages and disadvantages and is best suited to a particular problem which cannot be generalised. The method chosen to forecast Iraqi seaborne trade will be discussed in section 4.5.3 where availability of data is severely limited and competition between ports or different modes of transport does not exist.

It was mentioned earlier in this Chapter that queueing theory is used in simple cases while simulation is used in more complex cases, evaluating against the stated criteria we can see from the discussion provided earlier on these techniques that both techniques satisfy first and second criteria except that queueing theory cannot deal with emperical distributions, nor can it provide waiting times, idle times and queue lengths for different cargo and ship types for different berths unless they are similar and the cargo is of homogeneous commodity.

While queueing theory fails to satisfy criteria 3, 4 and 5; simulation can easily accommodate shift times, tidal times, deals with multi-purpose (multi-commodity) ports and berths shared by different ships. Hence, judged against the stated criteria above, simulation is by far a more superior technique compared to queueing theory, although each has its advantages and disadvantages when applied to a particular problem as was discussed in section 4.3 above.

Finally, as far as investment appraisal is concerned from the discussion provided in section 4.4, it becomes obvious that the average rate of return and pay-back method does not satisfy any of the stated criteria. While the other three techniques satisfy the first criteria, only the NPV satisfies the second criteria and the other two result in high values with further additional increases in berth investments as explained on pages 60 and 61.

Unfortunately, none of those methods satisfy the third criterion and a method to overcome this difficulty has to be developed.

Since this study is concerned with Iraqi ports which are in no way different from other ports all over the world except that the data available for forecasting future demand is severely limited and restricted, the next section will deal with the chosen methods for planning the Iraqi ports.

4.5.3 Chosen Methods

There are three ports in Iraq all situated in Basra on the Arabian Gulf few miles apart from each other, two of the ports are multi-purpose catering for different cargo and ship types and the third port will become a multi-purpose port before 1985. As mentioned in Chapter 2 about 90 percent of trade is carried by maritime transport hence arriving to one point and then distributed all over the country. All modes of transport (air, sea and land) are operated by the government and hence there is no competition between the ports nor by the different modes of transport.

In considering the choices of the appropriate forecasting method, the data concerning the preparation of input-output tables could not be obtained and even if it could be, it might take lengthy time periods to prepare, making this study an extremely lengthy one. The use of gravity models, since the ports are situated in one area and the volume of maritime transport is almost 90 percent of the total trade, becomes redundant even if traffic data could be split on hinterland areas and the aim of the study is to minimise transportation costs, which is not.

Time series analysis can be based on past trends, but because of the limitations mentioned earlier such as the introduction of a new commodity, the variations in the volume of local production which have a direct effect on imports and exports, makes it unreliable to predict future trade based on past data. Finally, since the ports are inoperational presently and it is impossible to consult all the parties involved, especially shippers and ship owners, scenario writing is restricted to the knowledge of the port authorities and the planning authorities.

Hence a different forecasting model will be developed linking seaborne trade to economic growth, consumption, production and population growth. That is the higher the consumption of a particular commodity and the higher the economic and population growth, the higher the volume of imports. If the commodity is locally produced (partly), then the higher the volume of local production, the smaller the volume of imports and vice versa. This is shown in the block diagram in figure 4.3, and the details of the model will be discussed in Chapter 5.

Since the ports are multipurpose, operate for two shifts a day and are tidal (that is ships can approach and leave the berths during the working hours and when there are tides), simulation will be used to model the arrival and departure of ships in order to determine the waiting times and queue lengths of ships together with the idle times of berths. This is shown in figure 4.3, and the details of the model discussed in Chapter 6.

Finally, a model will be developed to arrive at an optimum investment strategy for the years 1985, 1990, 1995 and 2000 making use of the NPV method in order to find the minimum cost point, by plotting the discounted costs of construction and the benefits obtained from reducing congestion against an increasing number of berth additions. This model will later be extended to arrive at an optimum investment strategy at any future time period in addition to the four periods mentioned above. This is shown in figure 4.3, and the details of the model will be discussed in Chapter 8

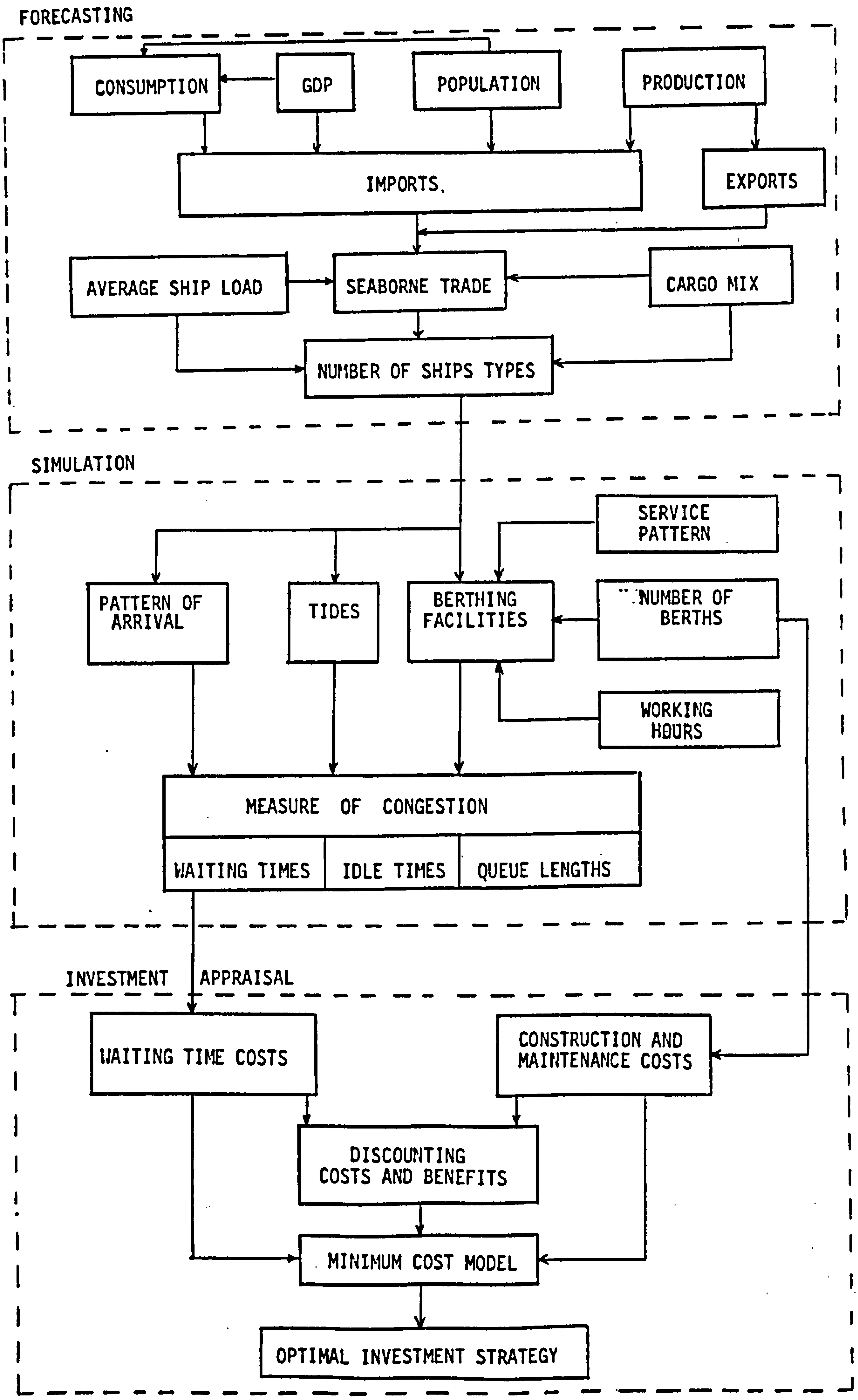


FIGURE 4.3 BLOCK DIAGRAM SHOWING LINKS BETWEEN METHODS OF CHOSEN STRATEGY

CHAPTER 5

FORECASTING SEABORNE TRADE

5.1 Introduction

The aim of this chapter is to determine the total demand tonnage for imports and exports and the number of ships and their types calling at the port at any future time period.

It was illustrated in Chapter 1 of this study that almost all port planning studies conducted to date appear to have ignored seaborne trade forecasts assuming that they were either known or provided by a separate study conducted by consulting firms or the country concerned. However, gravity models were used in the Portbury study (Ministry of Transport 1966) and resulted in extremely poor forecasts (Chu 1968); input-output models were used by (Leontief 1979) to make detailed projections of seaborne world trade; and econometric models were used by the (National Port's Council 1976) to forecast UK seaborne trade for the years 1980 and 1985. It was also mentioned in Chapter 1 of this study that the above models rely heavily on the availability of highly disaggregated high quality statistical data, a requirement many ports and countries cannot meet, and such models are very maintenance intensive. The suitability of forecasting techniques especially where data is very scarce and limited, was discussed in sections 4.2 and 4.5.

In the next section the factors influencing demand forecasting will be discussed. Effects of changes in competition will be discussed.in section 5.3. Technological changes and their implications will be discussed in section 5.4.

The analysis of imports and the imports forecasting model will be provided in sections 5.5 and 5.6 respectively. In sections 5.7 and 5.8 exports analysis and the exports forecasting model will be provided. Finally, in section 5.9 cargo classification and ships forecasting model is provided.

5.2 Factors Influencing Demand Forecasting

Demand for imports is by and large related to the growth of the economy. As domestic output rises or falls, imports for raw materials, semi-finished goods, fuels, machinery, ... etc., are expected to rise and fall in the same manner. As incomes increase or decrease, imports of finished goods will probably move in the same direction (Stanlake 1984). If a country's income increases, the rise in the country's income will bring about an increase in its imports from the rest of the world (or those countries trading with it).

In addition to the growth in the economy, imports - to a lesser degree - will also be affected by changes in the country's policy with regard to tariffs, quotas and other restrictions on international trade. More general considerations like the strength of the commercial links between the trading partners, closeness of cultural as well as political ties can generate a level of trade not otherwise expected on purely commercial grounds.

Overseas demand for exports depends on the level of world economic activity and the competitiveness of the country's export prices. Export prices in turn are influenced by the productivity measured as total output per man-hour. Export demand functions are influenced by the price of the commodity relative to those in the rest of the world, economic growth and rates of inflation in the importing countries, and the general state of the world's recession.

From the foregoing discussion, trade flows represented by the countries Iraq trades with can be determined by demand functions and supply functions. Prices which enter the demand function include exchange rate, tariff and transport cost elements. Other factors that have an effect on imports and exports are inflation rates and the closeness of cultural and commercial ties between two countries.

Where ports are concerned, a number of additional non-economic variables such as competition between ports and changes in technology have to be taken into account. Competition could increase or decrease the port's share of trade by providing better services, relieving congestion, improved facilities, trans-shipment and lower or higher tariffs, while changes in technology might result in larger, faster and more modern ships and the unitisation of cargo. The factors influencing demand forecasts are illustrated in figure 5.1.

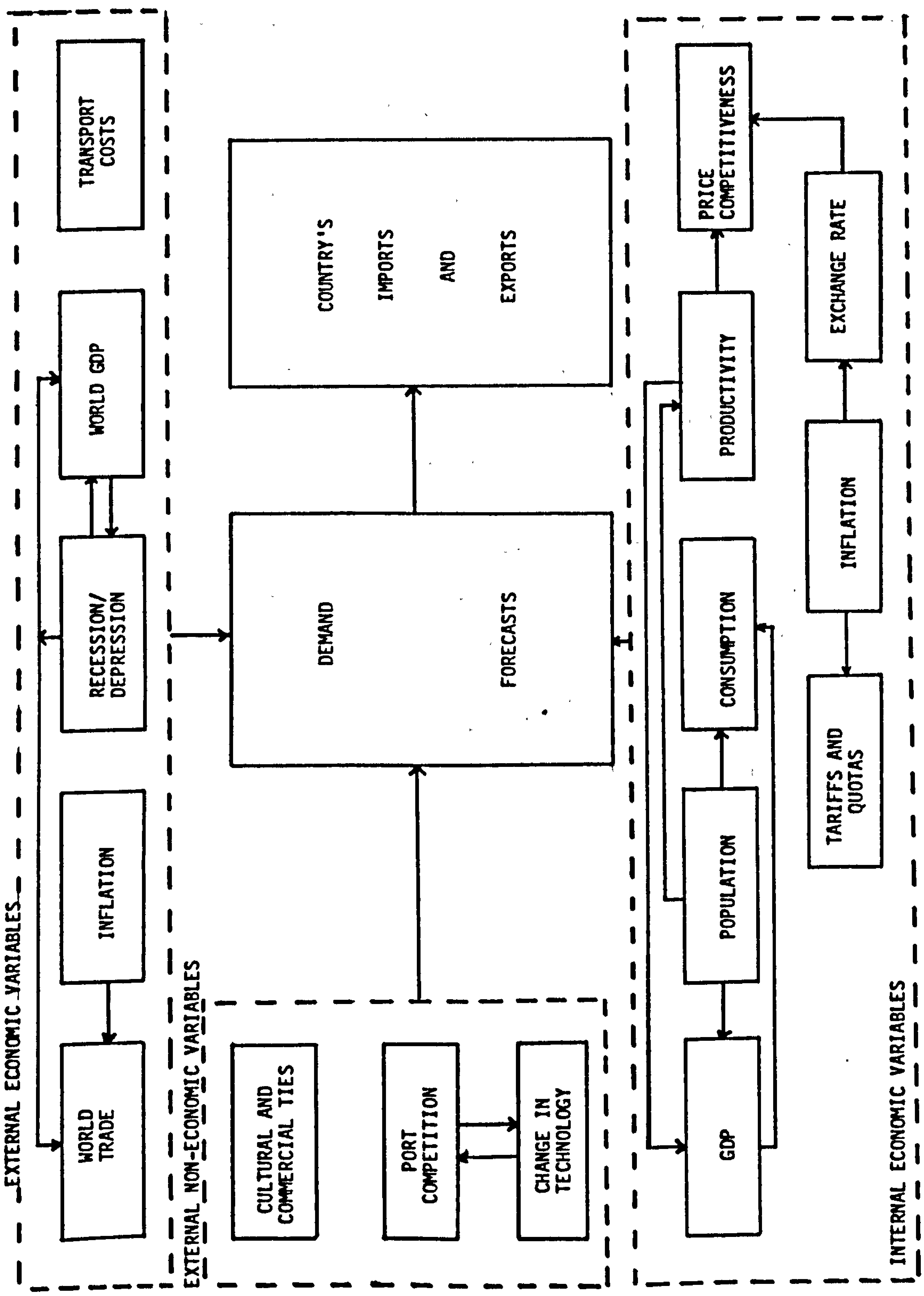


Figure 5.1 VARIABLES INFLUENCING DEMAND FORECASTS

It can be seen from figure 5.1 that demand is a function of external economic variables, internal economic variables and external non-economic variables. In addition each variable in figure 5.1 is a function of a number of other variables, the relationship of which is not easy to quantify. For example, exchange rate could be a function of economic activity, foreign reserves, inflation, unemployment, strikes, ... etc.

Since we live in a dynamic world where changes take place every day, it will be very difficult to build and maintain a forecasting model incorporating all the variables shown in figure 5.1, especially for a developing country where basic data is very scarce and a more realistic model is sought.

It was mentioned in this section that trade flows can be determined by demand functions and supply functions (see figure 5.2). Exchange rates, inflation .... etc., will influence the price of each commodity and hence the quantity demanded. Due to the limitations on the availability of data, it will be assumed that the government will use compensating factors in the form of lower or higher tariffs, change of quotas and other restrictive measures to compensate for variations in exchange rates, inflation ... etc. and restore demand to what it was (Q_0). This implies that demand will be mainly influenced by the internal (domestic) economic variables which will provide the basis of the forecasting model in this study.

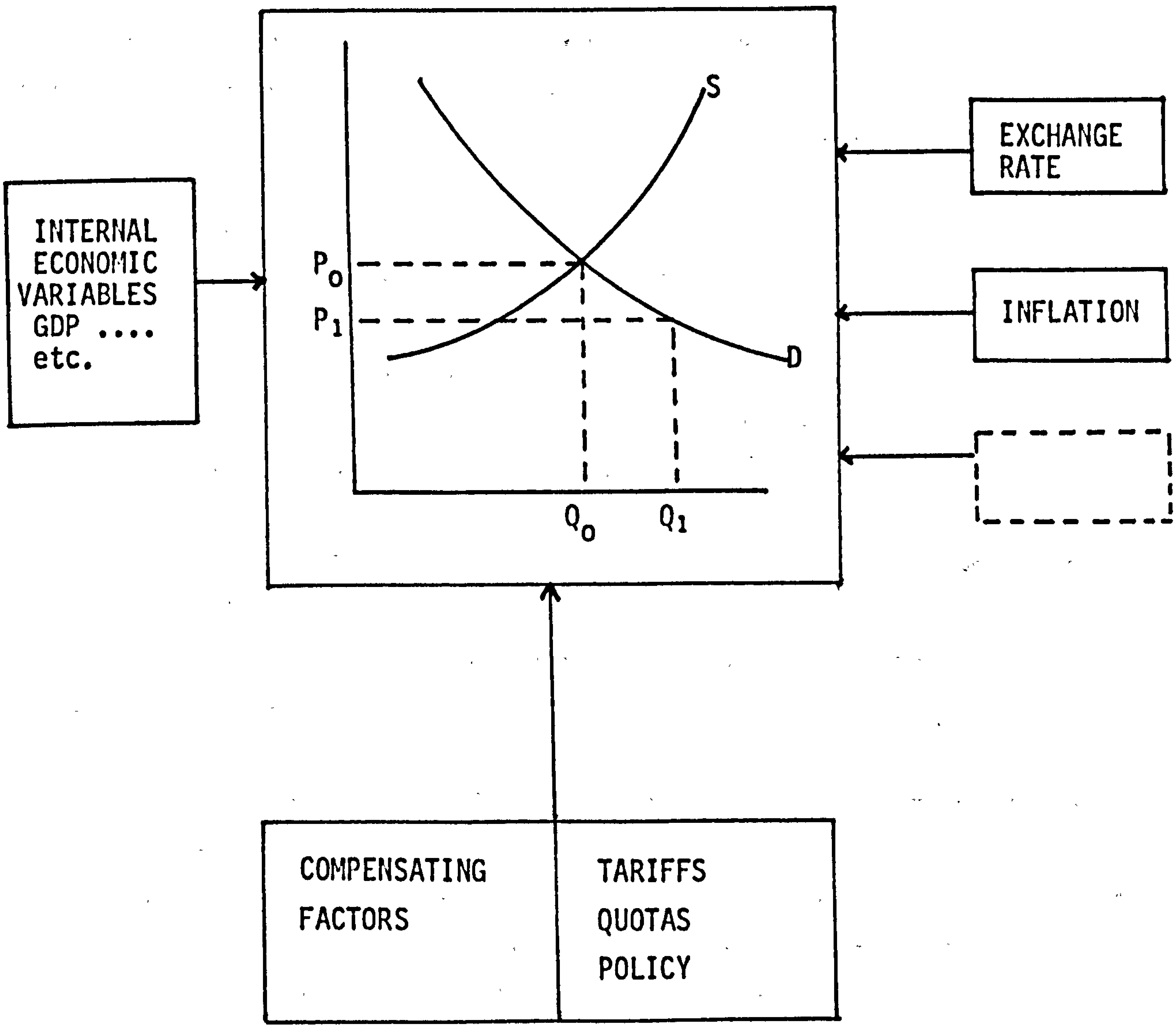


Figure 5.2 KEEPING DEMAND CONSTANT

5.3 Effects of Changes in Competition

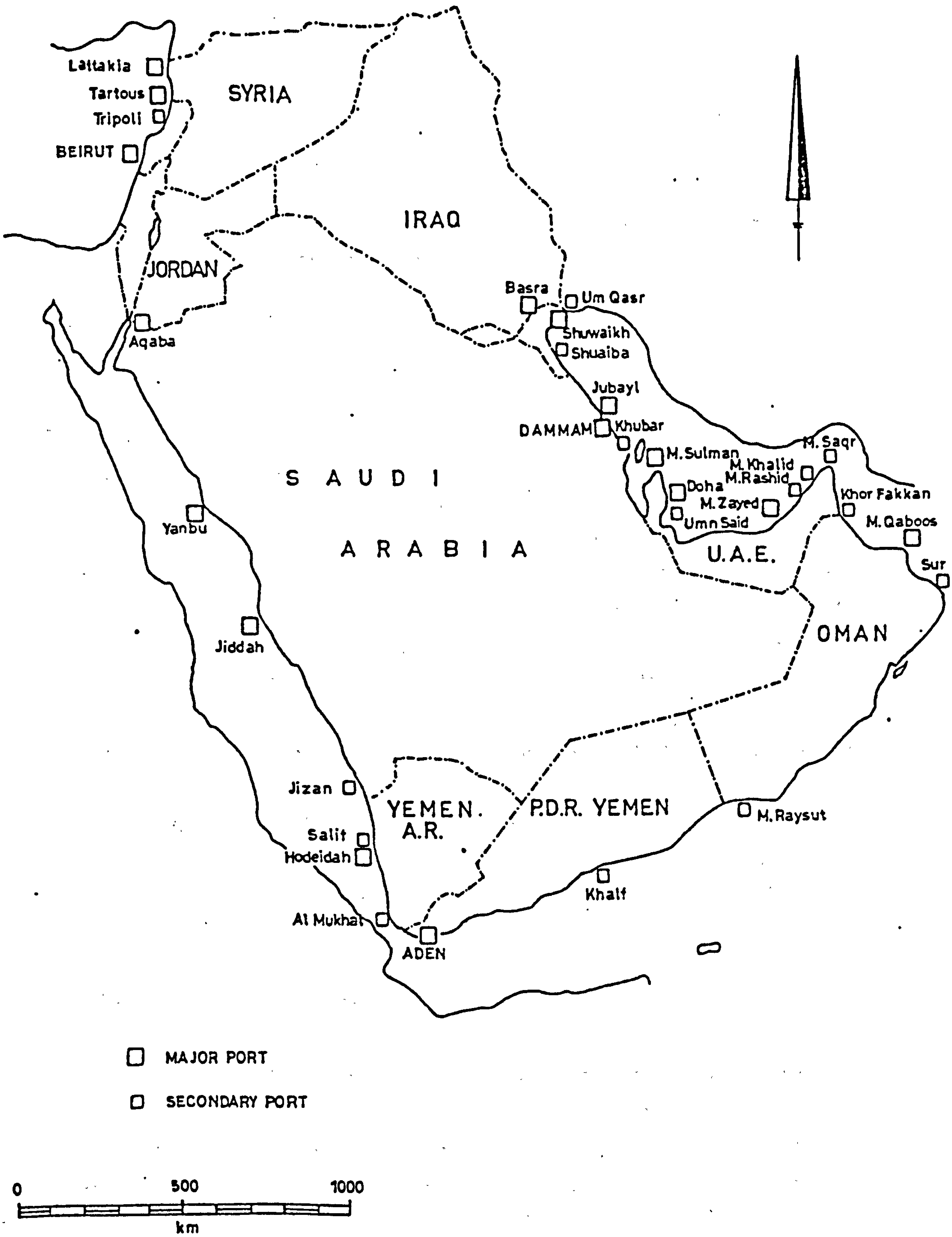
Competition among ports takes place where two or more of them share a continuous hinterland and where trans-shipment is involved. In the first case, ports compete for the business of importers and exporters who could route their goods through any one of the ports and could switch from one port to another as congestion at one port quickly leads to vessels being diverted to the other (Benathan and Walters 1979).

In the second case, a commodity shipped from abroad to Basra may be shipped direct from abroad to Basra or may be transported to Kuwait and then trans-shipped to Basra. In this sense, Kuwait competes with Iraq. But Kuwait may also be competing with an alternative trans-shipment port such as Saudi Arabia. In such a case of pure trans-shipment competition, the interest of Iraq (assuming that it cannot hope to get the cargo direct to its ports) is to obtain the most competitively low rate no matter where the goods are trans-shipped.

Inland and trans-shipment competition in the Arabian Gulf region and their effects on Iraqi ports will be discussed in this section. The relative sizes of ports in the region will be described, the hinterlands served and the distance of the consumer and industrial centres in Iraq from neighbouring ports will be discussed, and finally a range of issues and policies of the ports in the region will be provided.

5.3.1 Relative Sizes of Ports

It was mentioned in section 2.6 of Chapter 2 that there are 3 commercial ports in Iraq located at the south of the nation on the Arabian Gulf. The sizes of the ports in 1979 is shown in Table 2.2 of Chapter 2. There are many other ports in the region such as Shuwaikh and Shuwaiba in Kuwait, Jubail and Dammam in Saudi Arabia and many others further down south on the Arabian Gulf. In addition there are a number of ports on the Mediterranean such as Latakia and Tartous in Syria and Beruit in Lebanon, and a number of ports on the red sea like Aqaba in Jordan and Yanbu, Jiddah ahd Jizan in Saudi Arabia (see map on next page).



PORTS IN WESTERN ASIA
APRIL 1979

The relative sizes of the Gulf and Red Sea ports in berth number and cargo handled (tons) in 1979 is shown in Table 5.1.

As can be seen from Table 5.1 the Saudi ports are the largest and probably the most developed in the region. Since 1979 all ports have expanded considerably (even though the Iraqi ports are not functional presently due to the Gulf war, nevertheless, Um Qasr and Khor Al-Zubair ports are being expanded considerably).

In 1980, Saudi imports valued at over SR 100 billion (£24 billion) vital to the Kingdom's development was the main reason for developing the ports and since then they have embarked on their Third Development plan allocating SR 24 billion (£5.6 billion) for further expansion of the ports(1). The annual growth in foreign trade volumes for the years 1973-1976 (percentage) excluding crude and refined oil has been 30 percent for exports and 44 percent in imports, and therefore it is not surprising that their ports which are vital to the country are expanding at such a staggering rate.

In 1976 transshipment trade from Dhubai (United Arab Emirates), the largest transshipment centre in the southern sub-region to Oman, accounted for 36 percent of the total trade in value terms, Saudi Arabia, Iran and Qatar were the other major recipients. In tonnage terms the transshipment trade through Dhubai to all destinations was 657,000 tons(2) which is really negligible.

5.3.2 Hinterlands Served by Ports

It was mentioned in Chapter 1 of this study that over 90 percent of trade in Iraq is carried by maritime cargo, and therefore all consumer and manufacturing centres in Iraq are served almost exclusively by ports. Looking at the map of Iraq in Chapter 2, it can be seen that all major towns and cities in Iraq are concentrated in the middle and eastern border of the country, the western border of the country being mainly desert land (near Jordan and Syria).

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1 Kingdom of Saudi Arabia Ports Authority, Report No. 3, 1980

2 ECWA United Nations Publication, 1980

TABLE 5.1 Gulf and Red Sea Ports[1]

COUNTRY	GULF PORTS	TYPE OF BERTH			CARGO HANDLED (Million tons)
		General	Unit-ised	Bulk	
IRAQ	Basra	15		4	4.6
	Um Qasr	4	1	4	1.9
	Khor Al-Zubair			1	0.14
KUWAIT	Shuwaikh	18			4.4
	Shuaiba	4		1	1.0
SAUDI	Jubail	2	1	2	not available
	Dammam	23	3	2	8.7
	RED SEA PORTS				
JORDAN	Aqaba	3	2	2	not available
SAUDI	Yanbou	1		2	1.0
	Jeddah	26	9	10	12.5
	Gizan	1		2	1.0

1 ECWA UNITED NATIONS PUBLICATION, 1980

As can be seen from the map of ports in western Asia, the Iraqi ports of Basra, Um Qasr and Khor Al-Zubair are the nearest ports to all major cities in Iraq such as Basra, Nasiriyah, Amarah, Hillah and Najaf in the south; Kerbala, Kut, Baghdad, Baquba and Tikrit in the middle; and Kirkuk, Sulaimaniya, Arbil and Mosul in the north.

All those major cities (see maps in Chapter 2) are linked by railways to Baghdad, Basra and the ports and by motorway roads. There are no railways linking those cities to any neighbouring ports, but roads linking Jordan and Syria to Baghdad, and Kuwait to Basra are available. The charges of road transport for some countries is shown in Table 5.2.

Country	Charges per ton/km
Iraq	2.0 - 5.0
Jordan	2.8 - 6.3
Syria	1.2 - 3.3
Oman	5.0 - 10.6
Saudi Arabia	3.7 - 7.4

Table 5.2 Trucking charges (US $cents)[1]

It can be seen from Table 5.2 that even if some commodities have to be transported by road, it is much cheaper if they are transported from the Iraqi ports to any destination in Iraq even if they come via the Syrian port of Latakia and then to Baghdad, which for the past 10 years there is no trade via Syria.

The only ports that are close to Basra in the southern region of Iraq are the Kuwaiti ports of Schuwaikh and Shuaiba and the rest of the ports are very far especially those on the Red Sea and the other Gulf States. Therefore it makes little sense to import or export through ports other than the Iraqi ports in normal circumstances.

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1 ECWA United Nations Publication, 1980

5.3.3 Range of Issues and Policies of the Ports

From the foregoing discussion in the previous sections, it is clear that neighbouring ports will have very little effect if any on the Iraqi ports in normal circumstances, especially when it is not appropriate for ports in developing countries to engage in competition or speculative investment (UNCTAD 1978).

Iraq is not a land locked country and therefore it is not forced to import through ports of neighbouring countries, nor will investment in Iraqi ports lag behind demand and hold back economic development. It can be seen that the berthing capacity of the ports for the 1981-85 plan is to be increased by over 270 per cent (see section 2.6 of Chapter 2). Therefore no diversion of vessels will take place to neighbouring ports due to congestion.

Since transshipment is so small among the Gulf states except in the case of Dhubai to Oman, it is not expected that transshipment will increase to Iraq partly because it is much cheaper and quicker to distribute the commodities from Iraqi ports to all other destinations in the country and avoid the double handling costs which will increase the overall costs of the goods considerably, and partly because it is much more convenient to export certain bulk commodities such as chemical fertilisers and urea direct from the Iraqi ports since the factories are so near the ports, and sulphur and phosphates where they are transported to the ports by rail direct from their factories. The same applies to the import of certain import commodities such as grains and iron and steel.

It must also be mentioned here that Iraq lies in a region of political unrest and it is vital to rely on its own ports at any future time because of the unstability in the region. The port of Beruit cannot be relied upon, the civil war in Lebanon has been going on for the past 10 years. The Syrian port of Latakia will have no effect whatsoever on Iraq since the relations broke with Syria in 1979 and the Syrians have stopped the exports of Iraqi crude oil passing through the Syrian territory. Aqaba port in Jordan is very close to Israel with a long history of conflict with the Arab states, and the rest of the ports in the region (apart from Kuwait) are too far from Iraq.

As far as the Kuwaiti ports are concerned, it is not known if they can handle an increasing portion of the growing Iraqi traffic in future years to come.

From the foregoing discussions, it becomes clear that competition from other ports is unlikely and since Iraq is one of the most potential countries in the region, it is less likely that it will depend to any significant extent on other ports in the region.

As mentioned in Chapter 2 of this study, all major businesses in Iraq are nationalized and all imports and exports are done by the government, hence, it can discourage Iraqi traffic from using other ports and induce traders to use the ports of Basra through keeping, for example, port charges low for Basra. The Iraqi railways which are government owned can discriminate in their rates in favour of the domestic ports and against neighbouring ones.

If, for any unforeseen reason, investment in ports lags behind demand hence creating a shortage in capacity, for example, in 1990 the port capacity might be able to handle say 10 million tonnes of cargo while demand could be, say 11 million tonnes, then the extra million tonnes would probably be handled by a neighbouring port, and this share could simply be subtracted from the Iraqi ports.

Here it has been considered that it is unlikely that competition from neighbouring ports will alter the general trend of the port forecasts over the period to the year 2000 presented in this chapter. However, should the political situation change in unexpected ways leading to either more competition or more co-operation with neighbouring ports, then the demand forecasts would have to be modified so that only a proportion enters/leaves through the Iraqi ports. This proportion would depend on the explicit competitive circumstances but could be reasonably calculated using concepts of hinterland definition or gravity models.

The simulation model and investment model would, however, remain the same, and the changed circumstances would simply require a new set of inputs (number of ships and their types) to be specified. The simulation model is flexible enough and is designed to allow for revised forecasts to be readily incorporated, and the results obtained would be analysed in the same manner through investment appraisal leading to the optimal number of berths for any amount of cargo. However, during the period of the present forecasts there is no evidence to lead one to the emergence of a situation which port competition may occur.

5.4 Technological Changes and their Implications

In the half-century between 1900-1950, world seaborne trade (dry bulk cargo and oil) increased from about 200 to 525 million tons[1]. During the period 1950-1973, total world seaborne trade increased six-fold, rising to 3,190 million tons of cargo and it seems likely that the demand for seaborne shipping services will continue to grow in the future. The world ocean shipping fleet experienced a period of rapid growth and great technological innovations in the past 20 years. Change was pervasive throughout the shipping industry, with tankers, dry bulk and liner cargo fleets all affected to an important extent. World fleet tonnage increased about 300 percent between the early 1960's and the mid-1970's, with an accelerating growth rate at an average annual rate of 8 percent during the early 1970's[2].

Substantial increase in the productivity of tanker and bulk carrier shipping were experienced between 1960 and 1975, largely relating to the increase in average ship size and speed, longer average cargo voyage distance, faster port turnaround and higher cargo load factors[3].

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1 Freight Markets and the Level and Structure of Freight Rates, United Nations Publication, 1972

2 Lloyds Register of Shipping; Statistical Tables (London) 1974

3 Review of Maritime Transport, United Nations Publication, 1972-73

5.4.1 Existing Technology

During the past 20 years, technological progress in the world shipbuilding industry has brought many far-reaching changes which have enhanced the efficiency of world shipping.

There has been a dramatic increase in vessel size. Between 1963 and 1974, the carrying capacity of the world fleet, measured in deadweight tons (dwt) increased almost three-fold, while the number of ships increased only 38 percent(1). This increase in ship size was largely confined to tankers and bulk carriers, on the average ships classed as "other ships" increased in size only marginally.

A dominant characteristic of the shipping industry in recent years has been the introduction of many new types of specialised ships. Some of these specialised types are designed to serve the needs of specific commodity trades, such as liquified gas carriers, chemical carriers, oil product tankers, car carriers and mineral slurry tankers.

The improvement of the handling of general cargo has been the objective of the expansion of the unitised cargo transport to handle containers, pallets and other types of unit loads. Several different ships and related cargo-handling concepts have been developed to replace traditional break-bulk handling, with the common goal of prepackaging cargo units to facilitate ship loading and unloading operations.

Lift-on/lift-off vessels include container ships and barge-carrying vessels. Container ships may be fully cellullar with installed guide rails to expedite container storage. Semi-container ships, with or without guide rails can carry containers and other types of cargo. Gearless container vessels require the availability of specialised lifting and transport equipment at their ports of call.

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1 Fearnley and Egers Company Limited, Review 1974, (Oslo - 1974).

There are two principle types of barge-carrying vessel now in service on deep sea trade routes, namely LASH (Lighter aboard ship) and SEABEE. Of the two types the LASH concept is the dominant one, 24 of the 27 ships in service being of this type. Barge-carriers can, in theory, operate independently of ports. However, since many barge-carriers also carry containers they are normally handled in the port area, often at a container berth.

Roll-on/roll-off vessels (ro/ro) an extension of the traditional ferry boat, accommodate lorries or other wheeled vehicles by means of a portable ramp. Ro/ros are used extensively in the short-sea trade.

With the emphasis on specialised ship types, there continues to be a widespread need for general cargo and multipurpose ships. A popular design in this category is the so-called "open ship" which has large quick-opening hatches, squared and levelled storage decks and fast-response crane of varying lifting capacities. Some of these vessels, called pallet carriers, have side port openings to facilitate the handling of pallets by forklift trucks.

Since the Second World War, there has been a continuing trend in favour of the motorship as against the steam turbine, because of the former's economy in fuel oil consumption. The power limitations of the diesel engines restrict their use in very large tankers. The number of installations of gas turbines and nuclear propulsion units are too few to discern any trend.

5.4.2 Future Trends in Shipping and their Implications

The current problem of inflation, recession and high fuel oil costs restrain the impetus for widespread technological change that characterised the revolution in tankers, bulk carriers and container ships of the last 20 years. Technological change in shipping during the next decade or two may be expected to be more evolutionary in nature and to consist of the more widespread application of the existing technology(1).

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1 Technological Progress in Shipping and Ports, United Nations Publication, 1975

The rapid growth of the total world fleet since 1960, which was largely influenced by the increase in tanker and bulk carrier fleets, is not likely to be repeated during the next decade. The present large surplus of tanker storage will have a particularly inhibiting effect on overall world fleet growth for many years to come. There will, however, be a need to replace a large portion of the ageing general cargo fleet either with specialised vessels or with modern general purpose ships.

5.4.2.1 Unitisation

The increasing costs of cargo handling in ports seem to lead to a further spread of unitisation. However, the form that unitisation will take and its means of ocean transport are less certain.

Containerisation, including the use of fully cellular container ships, has now largely saturated the general cargo trade between industrialised countries. The use of containers to developing countries is increasing, although moderated by the shortage of containerisable return cargoes and the investment required for container-handling facilities in port.

Other than containers, the use of pallet, pre-slinging and the aggregation of bulk cargoes after substantial handling cost advantages over break-bulk shipments. The modern multipurpose ship is the conventional solution, although widespread port congestion can limit its usefulness. Roll-on/roll-off vessels offer rapid port turnaround capabilities if suitable port installations are available.

Barge-carrying vessels can transport all forms of cargo and have the unique advantage that the motorship does not require elaborate port facilities. However, the composite barge-carrying vessels, that is, those carrying containers and barges, do need container facilities.

Major changes affecting the general cargo portion of ocean-borne trade have taken place during the last decade. For the forseeable future, the most important development will consist in the increasing application of these technologies, rather than any development not currently in operation.

The first stage of these changes was the use of the pallet as the basic cargo unit. A number of specially built multi-deck, equipped with side door elevators and flush decks to allow fast mechanised handling were introduced. The penetration of this ship type, however, has not met the expectations initially placed on it.

The next important stage was the use of containers and the development of the cellular container ship. Since their introduction in 1966, the number of these ships has increased continuously. All major trade routes between industrialised countries have been largely containerised. Further expansion of container services thereafter will involve mainly the trade routes of developing countries.

The application of the roll-on/roll-off concept in the deep sea trades represent an important innovator. Roll-on/roll-off ships offer a large degree of cargo flexibility which, on trade routes involving developing countries, could be a very important factor in establishing successful services. In spite of these advantages, roll-on/roll-off ships have not yet penetrated the deep sea routes of developing countries on a large scale.

As far as barge-carriers are concerned, with the exception of two ships, all barge-carriers at present in operation are owned and/or operated by the United States based companies. Of the 27 vessels in service, 17 are provided with cellular holds for the carriage of containers.

5.4.3 Technological Developments in General Cargo Trade and Developing Countries

A considerable amount of controversy during the last decade has been generated regarding the relative merits of the container ship as against other forms of unitisation. In fact there is evidence today that each of the unitised vessel types has an advantage over the other for a certain portion of the general cargo traffic on certain routes, it may be expected that a variety of ship types including a break-bulk general cargo ship will compete with a certain measure of success for the trade.

From the foregoing discussions, it is apparent that the continued progress of unitisation especially in containers is both inevitable and irreversible, while any developing country can influence the speed of development, to try and oppose unitisation entails certain risks. For the port, the major risk is probably that of the diversion of important traffic flows from the port. The risks for the country as a whole may be much more serious and include higher costs for imports, failure of exports to remain competitive or even loss of international shipment services. Thus, the first step by governments and port authorities in dealing with the transition problem is a recognition that the traditional cargo package has a relatively limited future.

An increasing number of ports in developing countries are already receiving various types of unit-loads especially containers and the trend is likely to continue. The numbers of containers being handled by ports in developing countries will certainly grow. Although the initiative for this comes from shipping lines in developed countries. Shipping lines in developed countries increasingly express their intentions to introduce unit services on routes linking developed and developing countries, developing countries may themselves expect to benefit in the long run.

5.4.4 Technological Changes in the Carriage of Bulk Traffic

The main technological development in the shipping of bulk cargoes has consisted in the steady trend towards larger vessels. The main characteristic of such vessels is specialisation in ship type, with the corresponding need for specialised port facility.

Existing port sites, owing to limitations on the dimensions of both the port and its access channels, are often unsuitable for large tankers and bulk carriers. Entrance channels not only have to be widened and deepened, but as a result of the increased depth, they often have to be considerably lengthened. For some countries, the natural depth of water off the coast is rather shallow. In the Arabian Gulf where a rocky seabed and shallow waters near the coast would make dredging costs to create and maintain the required access channel dimensions have become prohibitively expensive.

The greatest impact of this steady trend towards larger vessels has been felt in relation to oil terminals, since such terminals have to cope with the largest ships afloat. For those ports unable to accommodate a fully laden crude oil tanker, there remains the possibility of receiving a partly loaded vessel. Such a vessel could first discharge part of its cargo at a port offering the required depth for a fully laden vessel. Further calls would then be possible at ports with stricter draught limitations. This is applied in loading ports in the Arabian Gulf where a rocky seabed and shallow waters near the coast would make dredging cost in many ports extremely high(1).

Since technological changes take the form of a swing to traffic unitisation and larger vessels, the effects of technological changes will be mainly in the form of rapid containerisation and slightly larger vessels due to the restriction on the depth of the dredged channels (see section 5.9 and Tables 5.18, 5.20).

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1 Technological Progress in Shipping and Ports
United Nations Publication, 1975

5.5 Analysis of Imports

The data that could be obtained concerning imports through the ports is summarised in Table 5.3, total production and consumption figures for the items that are locally produced is shown in Table 5.4, and the consumption figures for all the items together with GDP and population figures is shown in Table 5.5. The limitations on the availability of data impose restrictions on the forecasting model that can be developed. It was mentioned in section 5.2 that the forecasting model will be based on the internal (domestic) economic variables, that is, a forecasting model linking future demand to consumption, production, population, economic growth and elasticity of demand will be developed.

Table 5.3 shows that the volume of imports has doubled in 1979 compared to that of 1974, and that only three items, namely 11 (iron and steel), 12 (grains), and 23 (others) make up for over 74 percent of the total amount of imports (1188485 + 1610521 + 1250271 = 4049577/5423034 = 74.67); six items namely 5 (cement), 6 (drugs), 8 (food), 15 (oils), 19 (sugar), and 22 (timber) make up a further 20 percent (1100045/5423034 = 20.28); while the rest of the fourteen items make up for just over 5 percent of the total volume of imports.

Since forecasting is done under uncertainty and for a long time into the future, three forecasts, optimistic (based on the optimistic growth in the economy), most likely (based on the most likely growth) and pessimistic (based on the pessimistic growth) will be prepared for the nine items making almost 95 per cent of the total amount of imports, and only one forecast will be prepared for the rest of the fourteen items since the difference between the three forecasts for those items will be small and insignificant when compared to the total amounts of imports.

It was mentioned in section 5.2 that demand for imports is, by and large, related to the growth of the economy, this is true of items 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 16, 17, 18, 20, 22 and 23, that is, the higher the GDP and the per capita income, the higher the consumption of the above items; more people will be owning cars, more cement, timber, steel, ... etc., will be needed for the construction of houses and projects .... etc.

TABLE 5.3 IMPORTS THROUGH IRAQI PORTS (TONS)

ITEM	74	75	76	77	78	79
1. Alcohol, Wine, Tobacco, Cigarettes	5113	6412	6974	8180	9488	10385
2. Automobiles and Parts	8663	10560	11303	14522	15575	16747
3. Coal and Coke	4953	5274	5371	5686	5839	6101
4. Cotton, Wool, Silk, Nylon Products	14885	14990	15044	15061	15205	15262
5. Cement	132806	138227	146762	152148	161969	162491
6. Drugs and Chemicals	61752	76363	83587	96904	108463	126541
7. Electrical Goods	11729	14976	16981	19433	22550	25461
8. Food	23095	49325	63260	91596	116320	143191
9. Glassware	9658	10955	11381	12148	13517	14344
10. Gunnies (Jute Bags)	9204	10320	10411	11332	12462	13385
11. Iron and Steel	634935	780233	832246	948548	1060075	1188485
12. Grains	660791	1120241	767528	1097802	1251645	1610521
13. Leather	2624	2941	2880	3521	3436	3683
14. Machinery	18329	21418	23757	26416	28870	32288
15. Oils	99412	108911	110932	120591	131841	137045
16. Paper	21336	32112	34045	41599	53413	58871
17. Paints	1956	1867	1734	2265	1964	1613
18. Refrigerators, T.V., Radio	10188	12312	13112	17503	23008	25677
19. Sugar	303257	321718	333550	364632	328087	340254
20. Tar	8229	11735	14435	16408	18532	20105
21. Tea	24095	25976	26239	27795	28299	29490
22. Timber	99539	122670	131215	154259	166336	190523
23. Others	548034	566475	767646	523369	614103	1250571
TOTAL	2715417	3466011	3430393	3771718	4190997	5423034

Source - Iraqi Ports Organisation

TABLE 5.4 IMPORTS, LOCAL PRODUCTION AND TOTAL CONSUMPTION (TON)

ITEM		YEAR	1974	1975	1976	1977	1978	1979
3.[1]	Coal & Coke	a - Imports	4,953	5,274	5,371	5,686	5,839	6,101
		b - Local Production	16,000	18,000	21,000	24,000	27,000	30,000
		c - Total Consumption	20,953	23,274	26,371	29,686	32,839	36,101
4.[2]	Cotton ...	a	14,885	14,990	15,044	15,061	15,205	15,262
		b	7,000	12,000	15,000	20,000	24,000	30,000
		c	21,885	26,990	30,044	35,061	39,205	45,262
5.[3]	Cement	a	132,806	138,227	146,762	152,148	161,969	162,491
		b	2,400,000	2,900,000	3,200,000	3,800,000	4,600,000	5,300,000
		c	2,532,806	3,038,227	3,346,762	3,952,148	4,761,969	5,462,491
8.	Food	a	23,095	49,325	63,260	91,596	116,320	143,191
		b			NOT AVA	ILABLE		
		c						
10.[2]	Gunnies	a	9,204	10,320	10,411	11,332	12,462	13,385
		b	4,000	5,000	6,000	7,000	8,000	9,000
		c	13,204	15,320	16,411	18,332	20,462	22,385
12.[1]	Grains	a	660,791	1,120,241	767,528	1,097,802	1,251,645	1,610,521
		b	1,290,000	891,000	1,302,000	996,000	1,039,000	712,000
		c	1,950,791	2,011,241	2,069,528	2,093,802	2,290,645	2,322,521
13.[4]	Leather	a	2,624	2,941	2,880	3,521	3,436	3,683
		b	16,000	18,000	19,000	21,000	23,000	26,000
		c	18,624	20,941	21,880	24,521	26,436	29,683
16.[4]	Paper	a	21,336	32,112	34,045	41,599	53,413	58,871
		b	23,000	21,000	23,000	28,000	24,000	26,000
		c	44,336	53,112	57,045	69,599	77,413	84,871
17.	Paints	a	1,956	1,867	1,734	2,265	1,964	1,613
		b			NOT AVA	ILABLE		
		c						
20.[5]	Tar	a	8,229	11,735	14,435	16,408	18,532	20,105
		b	380,000	470,000	540,000	620,000	710,000	800,000
		c	388,229	481,735	554,435	636,408	728,532	820,105

1 Source for local production figures - Ministry of Agriculture
2 Source for local production figures - State Organisation for Spinning and Weaving - Ministry of Industry
3 Source for local production figures - State Organisation for Construction Industries - Ministry of Industry
4 Source for local production figures - State Organisation for Chemical Industries - Ministry of Industry
5 Source for local production figures - Ministry of Oil

TABLE 5.5 CONSUMPTION (Ton), GDP AND POPULATION FIGURES

ITEM / YEAR	74	75	76	77	78	79
1. Alcohol, Wine, Tobacco, Cigarettes	5,113	6,412	6,974	8,180	9,488	10,385
2. Automobiles and Parts	8,663	10,560	11,303	14,522	15,575	16,747
3. Coal and Coke	20,953	23,274	26,371	29,686	32,839	36,101
4. Cotton, Wool, Silk, Nylon Products	21,885	26,990	30,044	35,061	39,205	45,262
5. Cement	2,532,806	3,038,227	3,346,762	3,952,148	4,761,969	5,462,491
6. Drugs and Chemicals	61,752	76,363	83,587	96,904	108,463	126,541
7. Electrical Goods	11,729	14,976	16,981	19,433	22,550	25,461
8. Food	23,095	49,325	63,260	91,596	116,320	143,191
9. Glassware	9,658	10,955	11,381	12,148	13,517	14,344
10. Gunnies	13,204	15,320	16,411	18,332	20,462	22,385
11. Iron	634,935	780,233	832,246	948,548	1,060,075	1,188,485
12* Grains	1,950,791	2,011,241	2,069,528	2,093,802	2,290,645	2,322,521
13. Leather	18,624	20,941	21,880	24,521	26,436	29,683
14. Machinery	18,329	21,418	23,757	26,416	28,870	32,288
15* Oils	99,412	108,911	110,932	120,591	131,841	137,045
16. Paper	44,336	53,112	57,045	69,599	77,413	84,871
17. Paints	1,956	1,867	1,734	2,265	1,964	1,613
18. Refrigerators, TV's, Radios	10,188	12,312	13,112	17,503	23,008	25,677
19* Sugar	303,257	321,718	333,550	364,632	328,087	340,254
20. Tar	388,229	481,735	554,435	636,408	728,532	820,105
21* Tea	24,095	25,976	26,239	27,795	28,299	29,490
22. Timber	99,539	122,670	131,215	154,259	166,336	190,523
23. Others	548,034	566,475	767,646	523,369	614,103	1,250,571
GDP (M.I.D)[1] at constant prices of 1975	3,635	4,398	4,882	5,761	6,452	7,520
*Population (yearly increase 3.4%)	11,900,000	12,300,000	12,750,000	13,200,000	13,650,000	14,100,000

[1] Department of National Accounts - Ministry of Planning

[2] Central Statistical Organisation Ministry of Planning

On the other hand, items 12 (grains), 15 (oils), 19 (sugar), and 21 (tea) are dependent on population rather than GDP because if GDP is increasing at a higher rate than population growth, hence resulting in higher GDP per capita income, it does not follow that more grains ... etc. will be consumed since per capita saturation in those items has been reached.

Import items are made up of those commodities that are imported 100 percent from abroad because local production is either unlikely or insignificant at least to the end of this century for a number of reasons such as:-

1. local production is uneconomical or unprofitable
2. local production is not possible during this period
3. raw materials have to be imported which might make local production undesirable
4. unavailability of technology and technical know-how
5. it might be cheaper to import
6. the country has other priorities to concentrate on

and those items which are partly locally produced (see Table 5.4).

From the above discussion it follows that the majority of items are dependent on GDP and few others on population (see Table 5.6), and since some items are partly locally produced, the volume of imports will also be influenced by the rate of change of production, that is, the higher the local production the smaller the volume of imports and vice-versa, since consumption is made of imports plus local production (that is, Imports = Consumption - Local production).

5.5.1 Regression Analysis

The number of years for which data concerning imports could be obtained is only six (1974-79). During those years the volume of imports has been increasing and so has GDP and population (see Table 5.5).

It was mentioned in the previous section that most items are dependent on GDP, and since the data available is over a short time period, linear and exponential models could fit the data equally well.

The linear model is represented by:

$$I_t = a + b\ GDP_t \qquad 5.1$$

where I_t = imports in Time t
a = imports intercept
b = slope of the trend
GDP_t = gross domestic product in Time t

while the exponential model is represented by:

$$I_t = A\ GDP_t^{\alpha} \qquad 5.2$$

where I_t and GDP_t are the same as above, and
A is a constant
α is the elasticity of demand

To find out how good each of the above two models fits the data, the Department's Multiple Regression Package was used on a BBC microcomputer and the results of a, b, r^2; A, α, r^2 and the standard error of the equation for both models was obtained and is shown in Table 5.6.

Item	I = a + b GDP						I = A GDP$^{\alpha}$							
	a	st. error of a	b	st. error of b	r^2	st. error of eqn.	A	st. error of A	α	st. error of	r^2	mean T (log.)	st. error of eqn. (log)	st. error of eqn. natural (1)
1	241.777	396.516	1.382	0.071	0.989	225.365	0.203	0.160	0.987	0.043	0.992	3.8776	0.011	193.187
2	1893.77	1672.64	1.991	0.299	0.917	950.655	0.766	0.396	0.894	0.106	0.947	4.0944	0.027	796.433
3	6220.60	998.05	4.040	0.178	0.992	576.252	1.546	0.125	0.738	0.034	0.992	4.4426	0.009	580.184
4	551.659	516.726	5.977	0.092	0.999	293.687	0.812	0.064	0.993	0.017	0.999	4.5072	0.004	297.493
5	-357005	195598	772.986	34.966	0.992	111170.406	2.554	0.168	1.079	0.045	0.993	6.5705	0.012	104210.32
6	3094.74	1532.82	16.388	0.274	0.999	871.195	1.346	0.070	0.969	0.019	0.998	4.8533	0.005	826.015
7	-650.85	785.836	3.523	0.140	0.994	446.640	0.310	0.167	1.059	0.045	0.993	4.2537	0.012	502.470
8	-88924.7	4393.300	31.253	0.785	0.997	2496.985	-4.308	0.890	2.457	0.239	0.964	4.8402	0.015	2432.363
9	5476.63	436.90	1.199	0.078	0.983	248.315	2.065	0.117	0.540	0.031	0.987	4.0755	0.008	221.213
10	4736.01	450.72	2.380	0.081	0.995	256.170	1.521	0.068	0.809	0.018	0.998	4.2409	0.005	201.645
11	143807	27622	140.336	4.938	0.995	15699.570	2.792	0.109	0.848	0.029	0.995	5.9488	0.008	16523.871
*12	-159612	306757	175.818	23.587	0.933	43704.965	1.950	0.580	1.064	0.141	0.934	6.3261	0.009	44367.603
13	8323.80	310.64	2.822	0.056	0.998	176.554	2.004	0.082	0.635	0.022	0.995	4.1692	0.006	205.385
14	5803	684.43	3.561	0.122	0.995	389.005	1.511	0.076	0.774	0.020	0.997	4.3935	0.005	286.541
*15	-105189	16938	17.200	1.302	0.978	2413.283	-2.705	0.586	1.890	0.143	0.978	5.0696	0.009	2457.909
16	5454.55	3219.33	10.832	0.575	0.989	1829.747	1.352	0.150	0.925	0.040	0.992	4.7981	0.010	1463.272
17	2109.27	427.81	-0.038	0.076	0.060	243.153	3.661	0.796	-0.103	0.214	0.055	3.2762	0.055	255.016
18	-6253.93	2282.70	4.317	0.408	0.965	1297.401	-0.874	0.455	1.364	0.122	0.969	4.2051	0.031	1186.505
*19	137237	127048	14.995	9.679	0.371	18101.050	3.008	1.517	0.711	0.369	0.407	5.5203	0.023	18021.638
20	-6936.89	4334.01	111.831	4.350	0.994	13830.537	1.918	0.148	1.034	0.040	0.994	5.7660	0.010	13590.182
*21	-2676.89	2867.13	2.284	0.220	0.964	408.491	-0.125	0.458	1.108	0.111	0.961	4.4301	0.007	437.439
22	19060.5	4528	22.978	0.809	0.995	2573.564	1.884	0.111	0.877	0.030	0.995	5.1490	0.008	2620.063
23	-29595.3	2208.7	136.234	70.112	0.485	222961.669	2.902	1.796	0.787	0.482	0.399	5.8302	0.124	223517.516

1 Standard error of equation is worked out as follows:- For item 1 $10^{(3.8776 + 0.011)} - 10^{(3.8776)} = 193.1783$, the same is done for the rest of the items

* Regression of imports with population

TABLE 5.6 VALUES OF REGRESSION ANALYSIS

From Table 5.6 it can be seen that almost all items are highly correlated with GDP ($r^2 \approx 1$) except for items 17, 19 and 23. For items 17 (paints) there doesn't seem to be any correlation since GDP is increasing while imports seem to be decreasing, the decrease in imports could be due to the increased local production which is substituting imports (local production figures for this item could not be obtained). For item 19 (sugar) up to the year 1977 the imports are increasing and then declining in 1978 and 1979, the logical explanation for this is that sometimes more than needed is imported in the previous years, that is, there is over-stocking which obviously has an effect on the imports of the following years, hence resulting in a small r^2. Imports for item 23 (others) seem to fluctuate widely more than doubling in 1979 compared to all previous years.

Comparing the standard error of the equation (see Table 5.6), both the linear and the exponential models seem to fit the data equally well. The standard error in both models is very similar. Hence when $\alpha = 1$ (which it is very close to 1 for most items) and under the range of variations considered both the linear and the exponential models could be used resulting in equally close results (the difference being the constant a in the linear model).

Returning to equation 5.2 and differentiating with respect to GDP to obtain the rate of increase in imports, we get:

$$\frac{dI}{dGDP} = \alpha \, AGDP^{\alpha-1}$$

$$AGDP^{\alpha-1} = A\frac{GDP^{\alpha}}{GDP} = \frac{I}{GDP}$$

$$\frac{dI}{dGDP} = \alpha \frac{I}{GDP}$$

$$dI = \alpha I \, \frac{dGDP}{GDP} \qquad 5.3$$

In order to find the increase in imports, say between the years 1980 and 1979, using equation 5.3.

$$dI_{80-79} = I_{80} - I_{79} = I_{79}\ \alpha\ \frac{dGDP}{GDP}$$

$$I_{80} = I_{79}\ \left(1 + \alpha\ \frac{dGDP}{GDP}\right) \qquad 5.4$$

Similarly, $I_{81} = I_{80}\ \left(1 + \alpha\ \frac{dGDP}{GDP}\right)$

$$\vdots$$

$$I_{85} = I_{84}\ \left(1 + \alpha\ \frac{dGDP}{GDP}\right) \qquad 5.5$$

Equation 5.4 to 5.5 can be written more compactly as:

$$I_t = I_p\ (1 + \alpha\ GDP_r)^t, \text{ (see example below)} \qquad 5.6$$

where I_t = imports in time t
I_p = present imports
α = elasticity of demand
GDP_r = proportional change in GDP
t = year

To find the imports of item 1 (alcohol) in 1985 using equation 5.4 where $\alpha = 1$ and $GDP_r = 11\%$ (see section 5.6), yields:

$$I_{80} = 10385 \quad (1 + 0.11) = 11527.35$$
$$I_{81} = 11527.35\ (1 + 0.11) = 12795.35$$
$$I_{82} = 12795.35\ (1 + 0.11) = 14202$$
$$I_{83} = 14202 \quad (1 + 0.11) = 15765$$
$$I_{84} = 15765 \quad (1 + 0.11) = 17499$$
$$I_{85} = 17499 \quad (1 + 0.11) = 19424$$

Using equation 5.6 yields:

$$I_{85} = 10385\ (1 + 0.11)^6 = 19424$$

which is exactly the same.

The results obtained using the linear model (I = a + b GDP) and the exponential model $[I_t = I_p\ (1 + \alpha\ GDP_r)^t]$ for items 11 (iron), 12 (grains), and 23 (others) which make over 74 percent of the total imports is shown below:

Using the linear model

11 (iron) $I_t = 144 + 0.14o3\ GDP_t$

$$I_{85} = 144 + 0.1403\ (14065.5) = 2116$$

$$I_{90} = 144 + 0.1403\ (23701.2) = 3476$$

$$I_{95} = 144 + 0.1403\ (39937.9) = 5743$$

$$I_{2000} = 144 + 0.1403\ (67297.7) = 9579$$

12 (grains) $I_t = -160 + 0.1758\ (\text{Population}_t)$

$$I_{85} = -160 + 0.1758\ (17232.2) = 2896$$

$$I_{90} = 3420,\ I_{95} = 4072,\ I_{2000} = 4842$$

23 (others) $I_t = -29 + 0.136\ GDP_t$

$$I_{85} = 1884,\ I_{90} = 3194,\ I_{95} = 5420,\ I_{2000} = 9131$$

Using the exponential model

11 (iron) $I_{85} = I_{79}\ (1 + \alpha\ GDP_r)^6 = 1118\ (1 + 0.848 \times 0.11)^6 = 1909$

$$I_{90} = 1118\ (1 + 0.848 \times 0.11)^{11} = 2982$$

$$I_{95} = 1118\ (1 + 0.848 \times 0.11)^{16} = 4657$$

$$I_{2000} = 1118\ (1 + 0.848 \times 0.11)^{21} = 7274$$

12 (grains) $I_{85} = 2322\ (1 + 1.064 \times 0.034)^{6} = 2406$

$I_{90} = 2322\ (1 + 1.064 \times 0.034)^{11} = 3432$

$I_{95} = 2322\ (1 + 1.064 \times 0.034)^{16} = 4100$

$I_{2000} = 2322\ (1 + 1.064 \times 0.034)^{21} = 4897$

23 (others) $I_{85} = 1250\ (1 + 0.787 \times 0.11)^{6} = 2057$

$I_{90} = 1250\ (1 + 0.787 \times 0.11)^{11} = 3115$

$I_{95} = 1250\ (1 + 0.787 \times 0.11)^{16} = 4719$

$I_{2000} = 1250\ (1 + 0.787 \times 0.11)^{21} = 7147$

It can be seen that the results obtained from both models are similar since α is close to 1 for all three items. However, if the value of α is much greater (or lower) than 1, the results will be different. The results for item 8 (food) for example, where $\alpha = 2.457$, which means that every 1 percent increase in GDP has resulted in 2.457 percent increase in imports, are:

8 (food) Linear: $I_{2000} = -88924 + 31.253\ (67297.7) = 2{,}014{,}331$

Exponential: $I_{2000} = 143191\ (1 + 2.457 \times 0.11)^{21} = 21{,}763{,}693$

the implications for this item are discussed in the next section.

Since imports are, by and large, related to the growth of the economy and since the linear model does not incorporate the elasticity of demand α which provides the planning authorities with information to control the amount of imports in relation to national income, the exponential model seems to be more flexible in meeting future demand through changes in the value of α especially when it has been shown to fit the past data as good as the linear model. Exponential models similar to the ones used in this study have been used by (ARLT 1982) in predicting the cargo flow for ports, and therefore the exponential model will be used in this study.

5.5.2 Changes in Import Volume of Items

It can be seen that the imports for item 1 (alcohol) will continue to increase at the same rate as GDP (elasticity = 0.98, see Table 5.6) in future since there is no local production. The same applies to items 2 (automobiles), 6 (drugs), 7 (electrical goods), 11 (iron), 14 (machinery), 18 (refrigerators), and 22 (timber). For item 9 (glassware), the volume of imports will grow at half the rate of growth in GDP (elasticity = 0.54, see Table 5.6). The above items are imported 100 percent and dependent on GDP.

The items that are dependent on GDP but are partly imported and partly locally produced are discussed next. Since there is some local production for these items, there will be some import substitution. As mentioned earlier Imports = Consumption - Local production, which implies that imports are the result of the consumption trend less the production trend. Once the production trend is equal to the consumption trend (i.e. Local production is enough to cover local needs), imports will drop to zero. If production exceeds the consumption needs, exports can take place if so desired.

For item 3 (coal ..) imports represent 20 percent of local production (see Table 5.4) and since the country is a vast oil producer, oil and gas are expected to replace coal imports.

For item 4 (cotton ..), it can be seen from Table 5.4 that local production has gone up by 328 percent during the years 1974-79 and it is expected to go up further as there are plans to have many more factories[(1)]. Nevertheless imports of this item will continue to increase at half the rate of GDP in future (thus, the elasticity of demand $\alpha = 0.5$ instead of 1) allowing for different tastes and styles.

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1 Design and Construction Organisation - Ministry of Industry

For item 5 (cement), the country will be self-sufficient by 1985, many factories are under construction, some in their final stages[1]. This can be seen from Table 5.4 where imports represent no more than a mere 3 percent of local production in 1979.

Item 8 (food), local production figures were not available and this item comprises meat and meat products, eggs and dairy products, fish and fish products, fruits and vegetables. Measures to improve the cultivation of land, yield of crops, productivity of trees and fertility of live stocks are already underway. Imports of food (elasticity = 2.45, see Table 5.6) cannot be left to increase at such a high rate which will eventually drain GDP. It is assumed in these calculations that food will be imported at twice the rate of GDP until 1985 (thus $\alpha = 2$) then after decreasing until the country becomes self-sufficient by 1990[2].

Item 10 (gunnies), it can be seen from Table 5.4 that local production is increasing at a constant rate of 1000 tons per year, yet imports are not increasing significantly. Many factories producing plastic to replace gunnies (jute bags) are under construction[1] and the imports will increase at a smaller rate than that of GDP ($\alpha = 0.81$) until 1990, and then decreasing by 10 percent per year to the end of the century.

Item 13 (leather), local production has increased by over 62 percent while imports have increased by 40 percent during the same period. The growth of this item as can be seen from Table 5.5 is only 0.63 of GDP, and the increase in local production which is higher than the rate of increase in imports will eventually substitute imports.

Item 16 (paper), imports have been increasing at a much faster rate than local production. Imports have increased by 170 percent compared to 13 percent in local production for the period 1974-79, while the combined rate of growth is very nearly equal to that of GDP. Both imports and local production will continue at the same rate up till 1990, then after imports will grow at a slower rate and local production at a faster one

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1 Design and Construction Organisation - Ministry of Industry

2 Department of Planning and Research - Ministry of Agriculture

because of improved technology and the operation of more factories. By 1990 local production of paper will be around 200,000 tonnes increasing by 15 percent per annum to the end of the century[1].

Item 17 (paints), local production figures are not available, however, it can be seen from Table 5.3 that imports are decreasing. The reason being that the number of factories producing this item are increasing and so is their output. Imported paints in small quantities will continue since some types of foreign paints are desirable. Since the quantity of imports is so small, it can be discarded from the analysis without having any effect on the import volume, it will be assumed however that 2000 tonnes will be imported yearly to the end of the century.

Item 20 (tar), like cement, the country will be self-sufficient by 1985, tar is a by-product of many local industrial processes, mainly oil. The import volume of this item as can be seen from Table 5.4 represents 2.5 percent of local production and tar imports will be zero by 1985.

As for item 23 (others), it will be assumed that the rate of increase in imports will equal that of GDP ($\alpha = 1$). Looking at Table 5.5 it can be seen that the rate of increase for this item for the years 1974-79 has more than doubled (2.28-fold), while that for GDP for the same period was 2.07-fold which is very close.

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1 General Organisation for Chemical Industries

The items that are dependent on population are now considered. Item 15 (oils), 19 (sugar), and 21 (tea) are imported 100 percent and are expected to be imported at an increasing rate equal to that of the population growth rate of 3.4 percent for items 19 and 21, and twice the population growth rate for item 15 (see Table 5.6, elasticity = 1.89).

Item 12 (grains), local production figures could be obtained for the years 1971 - 1979 and they are shown in Table 5.7 below.

TABLE 5.7 LOCAL PRODUCTION OF GRAINS IN (000) TONNES

Year	71	72	73	74	75	76	77	78	79
Production	882	1625	957	1290	891	1302	996	1039	712

It can be seen from the table above that production is decreasing. The reason for this is that the gross cultivated area and the net harvested area vary from year to year. This item, because of its great volume of imports and its strategic importance to the nation cannot be left to increase forever, the country has shown great concern to step up production. Improved grains with higher yield per acré are being imported, more land is being reformed for cultivation and advanced technology will be used for harvesting. By 1985 vast fertile areas of land will be made available. In 1979 the gross cultivated area (measured in meshara) and the net harvested area were 4,311,000 mesharas and 4,188,000 mesharas respectively. The average yield in kilogram/meshara was 170 with a standard deviation of 11. The production in tonnes was 4,188,000 x 170/1000 = 712,000 tonnes. An area of 8,000,000 mesharas will be prepared to be cultivated and harvested before 1985 to be increased by 10 percent per year up to the year 2000[1], and the forecasting model will be based on this information.

[1] General Organisation of Land Reform - Ministry of Agriculture

From the foregoing discussion, the elasticities of demand α and β that will be used in the model are tabulated in Table 5.8 below:-

ITEM		Elasticity	
		α	β
1	Alcohol	1.00	
2	Automobiles	1.00	
3	Coal	0.73	
4	Cotton	0.50	
5	Cement	1.00	
6	Drugs	1.00	
7	Electrical goods	1.00	
8	Food	2.00	
9	Glassware	0.50	
10	Gunnies	0.81	
11	Iron	1.00	
12*	Grains		1.00
13	Leather	0.70	
14	Machinery	1.00	
15*	Oil		2.00
16	Paper	1.00	
17	Paints	--	
18	Refrigerators	1.00	
19*	Sugar		1.00
20	Tar	1.00	
21*	Tea		1.00
22	Timber	1.00	
23	Others	1.00	

Table 5.8 Elasticities of Demand

It was mentioned in Chapter 2 of this study that the national industry is not export orientated, especially for the items mentioned earlier in this chapter (Table 5.3) except for grains in future, and covering the country's needs through local production is the main priority[1].

In the next section the imports forecasting model will be developed.

1 Department of Foreign Trade - Ministry of Trade

5.6 Imports Forecasting Model

Economic expansion is estimated to increase by 11 percent per annum (most likely estimate) well into the next century going up to a maximum of 14 percent (optimistic) and a minimum of 8 percent (pessimistic)[1]. Population growth is estimated to grow by 3.4 percent (most likely estimate) per annum going up as high as 3.6 percent (optimistic) and as low as 3.2 percent (pessimistic)[2].

It was mentioned in section 4.5.3 of Chapter 4 that due to the limitations, restrictions and disadvantages imposed on using input-output analysis ... etc., a forecasting model linking seaborne trade to economic growth, production and consumption will be developed. Having obtained the values for these variables, and shown how they are related, the forecasting models for the different commodities are provided in this section.

It was mentioned earlier in section 5.5 that an increase of a constant ratio per unit of time implies that GDP and population will follow an exponential trend at least for the period 1985 - 2000. Since import items are dependent on GDP and population, they will also be expected to follow the same trend.

It could be argued here that economic growth cannot continue at 11 percent per annum for the coming 15 years and there could be lower growth rates before the end of the century. The same might apply to population growth. Similarly, consumption and hence imports which are dependent on GDP and population will be expected to drop.

It was mentioned in Chapter 2 of this study that economic expansion during the Seventies averaged more than 12 percent per annum. Iraq's oil reserves could be the second largest in the world and the economy is also rich in

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1 Department of National Accounts - Ministry of Planning

2 Central Statistical Organisation - Ministry of Planning

other minerals such as sulphur and phosphates. Only about one quarter of the total cultivable land is currently being utilised and the drive towards industrialisation is having modest progress. It is believed that the country's substantial hydrocarbon and other resources will provide the government with the financial resources required to develop the country's economy well into the future, and hence there is no reason to believe that economic growth is likely to slow down before the end of the century.

Whilst limitless growth cannot be sustained, a situation is reached where an absolute maximum or saturation value s is assumed to be reached, for example in developed countries such as the United States or Britain, car ownership cannot continue to grow exponentially since a saturation level of less than 0.4 cars per person has already been reached. Where saturation has been or is likely to be reached in the near future, an equation of the form

$$\frac{dy(t)}{dt} = \beta\, y(t)\left[s-y(t)\right] \qquad 5.7$$

could represent imports more accurately than the exponential trend. In the early stages, when $y(t)$ is small, equation 5.7 grows approximately to equal β s. In the late stages as $y(t)$ approaches saturation, the rate of change of $y(t)$ drops towards zero again. A plot of $y(t)$ against t shows an S-shaped curve. The solution to 5.7 is the logistic function (see Glaister 1981).

$$y(t) = \frac{s}{1 + k\, e^{-\beta st}} \qquad 5.8$$

where k is a constant such that $\log k = \beta st_0$.

While saturation levels of cars, TVs ... etc. have been reached or likely to be reached soon in most developed countries, it is unlikely that those levels will be reached in most developing countries including Iraq within 50 years time or more. Presently there are in the region of 350,000 cars in

Iraq with a population of over 14 million, that is approximately one car to every 40 people, and saturation is far from being reached even in 50 years.

It must also be mentioned here that Iraq is an under-populated developing country with a population of over 14 million people and twice the size of the UK, hence providing the foundation for rapid future growth both in population and the economy. The growth rates mentioned earlier together with huge hydrocarbon and other resources would suggest that the exponential model discussed earlier in section 5.5 reflects more accurately the growth of the economy and the imports. Nevertheless, if during the 15 years saturation takes place, then these can be readily incorporated into this interactive model.

The forecasting models in this section will be based on the latest available figures of imports, consumption, growth in GDP, growth in population, growth in production, and the elasticity of demand α (rate of increase in consumption to the rate of increase in GDP) and β (rate of increase in comsumption to the rate of increase in population).

Out of all the various imported items, the following are wholly imported and dependent on the level of GDP. They are items 1, 2, 6, 7, 9, 11, 14, 18, 22 and 23. Thus the forecasting model for these items will be:

$$I_t = I_p \, (1 + \alpha \, GDP_r)^t \qquad 5.9$$

where I_t = Imports in future at time t (1985, 1990, 1995, 2000)

I_p = present imports (1979)

GDP_r = rate of increase in GDP up to the year 2000

α = elasticity of demand relative to GDP

t = year

For the items that are partly imported and partly locally produced and dependent on GDP which are items 3, 4, 5, 8, 10, 13, 16, 17 and 20, the model will be

$$I_t = C_p\ (1 + \alpha\ GDP_r)^t - P_p\ (1 + PR_r)^t \qquad 5.10$$

where I_t, α, GDP_r and t are as in equation 5.9

C_p = present consumption

P_p = present production

PR_r = rate of increase in production

If the result of this equation (5.10) is negative, this means that production is in excess of the country's needs and exports can take place.

For the items that are imported 100 percent and are dependent on population which are items 15, 19 and 21, the model will be:

$$I_t = I_p\ (1 + \beta P_r)^t \qquad 5.11$$

where I_t, I_p and t are the same as in 5.9

β = Elasticity of demand relative to population

P_r = Population growth rate

Finally for item 12 which is partly imported and partly locally produced and dependent on population, the model will be:

$$I_t = C_p\ (1 + \beta P_r)^t - P_p\ (1 + PR_r)^t \qquad 5.12$$

where the values of α and β are shown in Table 5.9.

Using the models 5.9 to 5.12 to get the import figures for the years 1985 to 2000 at 5 year intervals and for the three different forecasts is shown in Appendix A, and Tables 5.9, 5.10 and 5.11 show the most likely, optimistic and pessimistic forecasts for imports for the years 1985, 1990, 1995 and 2000.

TABLE 5. 9 MOST LIKELY FORECASTS FOR IMPORTS (TON)

ITEM	1985	1990	1995	2000
1. Alcohol...	19,424	32,731	55,153	92,937
2. Automobiles...	31,324	52,782	88,941	149,871
3. Coal...	-	-	-	-
4. Cotton...	20,425	26,103	33,315	42,519
5. Cement	-	-	-	-
6. Drugs..	236,684	398,826	672,045	1,132,436
7. Electrical...	47,622	80,247	135,220	227,855
8. Food	472,144	-	-	-
9. Glassware	19,778	25,849	33,784	44,154
10. Gunnies	22,448	34,539	20,395	12,043
11. Iron...	2,222,960	3,745,816	6,311,918	10,635,949
12. Grains	1,478,460	1,164,653	437,921	-
13. Leather	-	-	-	-
14. Machinery	60,392	101,764	171,478	288,950
15. Oils	203,371	282,583	392,647	545,581
16. Paper	128,415	67,492	48,470	-
17. Paints	2,000	2,000	2,000	2,000
18. Refrigerators..	48,026	80,927	136,368	229,787
19. Sugar	415,840	491,506	580,925	686,630
20. Tar	-	-	-	-
21. Tea	36,041	42,599	50,350	59,512
22. Timber	356,357	600,482	1,011,847	1,705,022
23. Others	2,339,086	3,941,496	6,641,650	11,191,567
TOTAL	8,160,797	11,172,395	16,824,427	27,046,813

TABLE 5.10 OPTIMISTIC FORECASTS FOR IMPORTS (TON)

ITEM	1985	1990	1995	2000
1. Alcohol	19,424	32,731	55,153	92,937
2. Automobiles	31,324	52,782	88,941	149,871
3. Coal	-	-	-	-
4. Cotton	20,425	26,103	33,315	42,519
5. Cement	-	-	-	-
6. Drugs	277,754	534,791	1,029,695	1,982,591
7. Electrical	47,622	80,247	135,220	227,855
8. Food	629,760	-	-	-
9. Glassware	19,778	25,849	33,784	44,154
10. Gunnies	22,448	34,539	20,395	12,043
11. Iron	2,608,692	5,022,813	9,670,998	18,620,682
12. Grains	1,511,562	1,236,729	562,439	-
13. Leather	-	-	-	-
14. Machinery	60,392	101,764	171,478	288,950
15. Oils	207,985	294,446	416,849	590,138
16. Paper	128,415	67,492	48,470	-
17. Paint	2,000	2,000	2,000	2,000
18. Refrigerators	48,026	80,927	136,368	229,787
19. Sugar	420,689	502,065	599,182	715,085
20. Tar	-	-	-	-
21. Tea	36,041	42,599	50,350	59,512
22. Timber	418,192	805,194	1,550,333	2,985,034
23. Others	2,744,975	5,285,216	10,176,232	19,593,466
TOTAL	9,255,504	14,228,287	24,781,202	45,636,624

TABLE 5.11 PESSIMISTIC FORECASTS FOR IMPORTS (TON)

ITEM	1985	1990	1995	2000
1. Alcohol	19,424	32,731	55,153	92,937
2. Automobiles	31,324	52,782	88,941	149,871
3. Coal	-	-	-	-
4. Cotton	20,425	26,103	33,315	42,519
5. Cement	-	-	-	-
6. Drugs	200,804	295,048	433,552	636,986
7. Electrical	47,622	80,247	135,220	227,855
8. Food	348,870	-	-	-
9. Glassware	19,778	25,849	33,784	44,154
10. Gunnies	22,448	34,539	20,395	12,043
11. Iron	1,885,976	2,771,118	4,071,681	5,982,636
12. Grains	1,445,678	1,093,957	316,966	-
13. Leather	-	-	-	-
14. Machinery	60,392	101,764	171,478	288,950
15. Oils	198,844	271,157	369,767	504,240
16. Paper	128,415	67,492	48,470	-
17. Paint	2,000	2,000	2,000	2,000
18. Refrigerators	48,026	80,927	136,368	229,787
19. Sugar	411,037	481,149	563,220	659,290
20. Tar	-	-	-	-
21. Tea	36,041	42,599	50,350	59,512
22. Timber	302,336	444,230	652,720	952,720
23. Others	1,984,503	2,915,887	4,284,394	6,295,181
TOTAL	7,213,943	8,819,579	11,467,744	16,180,681

5.7 Analysis of Exports

The data that could be obtained concerning exports through the ports is summarised in Table 5.12. Analysis of Table 5.12 reveals that exports of some commodities are increasing at a very small rate and others are increasing at a very high rate. It can also be seen that the total voume of exports has gone up by 52 per cent in 1979 compared to 1974 and fluctuating widely during those years.

It is not possible to relate exports to GDP or population for it is obvious that GDP and population have been growing yearly while exports have not, nor have exports been increasing with time (years), hence a different forecasting model than the one adopted for imports should be looked for based mainly on the country's medium and long-range plans.

Analysing each item in Table 5.12 and starting with item 1 (dates), it can be seen that the rate of increase in the volume of exports over the years 1974 - 1979 is 6 per cent with an average of 0.6 per cent per annum. The reason for this is that the international demand for dates is almost constant limiting the amount of exports. It will therefore be assumed that the future volume of exports will continue at the present rate to the end of the century[1].

Items 3 (fuel oil), 5 (nephta), 6 (petrol), 7 (oil products) and 10 (white kerosine), it can be seen from Table 5.10 that exports have been decreasing sharply over the years to be zero or negligible by 1979. Local demand for those products has grown up largely to absorb most of the exports, plus the fact that most of the countries prefer to import oil and refine it locally. It is therefore assumed that the exports of these items will be negligible especially when the country has no intentions of expanding in this field except to cover local demand[2].

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1 Ministry of Agriculture

2 National Oil Company - Ministry of Oil

TABLE 5.12 EXPORTS THROUGH IRAQI PORTS (TONS)

ITEM	74	75	76	77	78	79
1. Dates	198375	201341	199624	203148	201513	204277
2. Fertilisers	6795	33440	66758	85749	121246	146709
3. Fuel Oil	123059	209582	122475	78686	32730	2304
4. Liquorice Roots	19263	48173	21465	16000	18047	-
5. Nephta	47537	112336	147699	186347	115810	-
6. Petrol	16001	41620	51218	39412	-	-
7. Oil Products	-	119731	73679	60509	-	-
8. Sulphur	258494	349722	374290	41213	18654	601498
9. Urea	-	-	-	45438	179675	276286
10. White Kerosine	101010	119802	105503	95316	45108	-
11. Others	111982	205265	116328	112641	108579	104066
TOTAL	882516	1441012	1279039	964459	841362	1335140

Item 4 (liquorice roots), exports have been fairly constant except for 1975 where there was a jump, and 1979 where exports were zero. It will be assumed that no more exports of liquorice roots will take place and can be ignored from the analysis without any effect since its volume is so small compared to other items and the total volume of exports.

Attention should be centred on items 2 (fertilisers), 8 (sulphur), 9 (urea), and phosphates where large plants are in their final stages and large quantities of this item will be exported in future. The rate of increase in the volume of exports of items 2, 8 and 9 and the geometric mean are shown in Table 5.13.

Item	75/74	76/75	77/76	78/77	79/78	mean
2. Fertilisers	392	99.6	28.4	37.9	21	62.05
8. Sulphur	35.3	7.0	-89	-54.7	3124	604.6
9. Urea	--	--	--	295	51.5	123.02

Table 5.13 Annual and mean percentage increase in the volume of exports

As can be seen from Table 5.12, the figures fluctuate widely for all three items and past data in this case is of very little use in trend projection especially for urea whose production is relatively recent and phosphates where production has not started yet.

As mentioned earlier in section 5.2 overseas demand for exports depends on the level of world economic activity and the competitiveness of the country's export prices. Since the world's economy is not in state of a recession and all the amounts produced of the above items have been exported in the past, it will be assumed that the country's export prices are competitive and will continue to be in the future. Otherwise, there is no point in investing hundreds of millions of Iraqi Dinars in factories whose products have no market.

For item 2 (fertilisers), the plants are partly utilised now, production is estimated to increase by 20 percent per year[1] where saturation will be reached by 1990 to equal the designed capacity of 1,000,000 tonnes per year.

For item 8 (sulphur), the volume of exports in 1977 and 1978 as can be seen from Table 5.12, was very small compared to the rest of the years. The reason was that during those two years a major production problem developed and sulphur could not be extracted where production had to come to almost a halt[2] until the fault was rectified by the end of 1978 and production was back to normal. The plants have been improved and modernised during those two years and it is estimated that the production will grow by about 9 percent per annum until 1990 where saturation will be reached and the export capacity will be 1,500,000 tonnes per year.

For item 9 (urea), the planned capacity of the plants to be achieved by 1985 is 750,000 tonnes increasing to reach the designed capacity of 1,000,000 tonnes per year by 1990[1].

The initial capacity for the production of phosphates is estimated to be 250,000 tonnes in 1985 increasing to the designed capacity of 1,500,000 tonnes by 1990[2].

The final item to be considered in Table 5.12 is 11 (others), it can be seen from this table that the export volume has been fairly constant at just over 100,000 tonnes per year except in 1975 where it was more than double this figure, and it will be assumed that the average volume of exports of 126,000 tonnes will continue throughout this century.

Based on the above discussion, it is possible now to proceed with the forecasting model for exports.

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1 General Organisation for Chemical Industries - Ministry of Industry

2 General Organisation for Minerals - Ministry of Industry

5.8 Exports Forecasting Model

The forecasting model that will be dealt with in this section will be based on the assumptions made in the previous section, namely the growth in the rate of production. Three forecasts will be made for fertilisers, sulphur, urea and phosphates while only one forecast will be made for dates and others. The figures given previously for the growth in production rates are the most likely ones, and the optimistic and pessimistic figures are given below.

The growth in production rates is estimated to go as high as 23 per cent and as low as 17 per cent for fertilisers. For sulphur it will be between 7 and 11 per cent. For urea it will be between 14 and 22 per cent and finally for phosphates it will be between 37 and 49 per cent.

The forecasting model for exports is

$$E_t = E_p (1 + PR_r)^t \qquad 5.13$$

where E_t = Exports in year t

E_p = Present exports

PR_r = Growth in production rate

t = Year

Using this model to get the export figures for the years 1985, 1990 1995 and 2000 for the three different forecast is shown in Appendix B and tables 5.14, 5.15 and 5.16 show the most likely, optimistic and pessimistic forecasts.

TABLE 5.14 MOST LIKELY FORECASTS FOR EXPORTS (TON)

ITEM	1985	1990	1995	2000
1. Dates	211,742	218,171	224,795	231,620
2. Fertilisers	438,070	1,000,000	1,000,000	1,000,000
8. Sulphur	1,023,866	1,500,000	1,500,000	1,500,000
9. Urea	750,000	1,000,000	1,000,000	1,000,000
11. Others	126,000	126,000	126,000	126,000
12. Grains	-	-	-	1,000,000
13. Phosphates	250,000	1,500,000	1,500,000	1,500,000
TOTAL	2,799,678	5,344,171	5,350,795	6,357,620

TABLE 5.15 OPTIMISTIC FORECASTS FOR EXPORTS (TON)

ITEM	1985	1990	1995	2000
1. Dates	211,742	218,171	224,795	231,620
2. Fertilisers	508,027	1,000,000	1,000,000	1,000,000
8. Sulphur	1,125,050	1,500,000	1,500,000	1,500,000
9. Urea	910,998	1,000,000	1,000,000	1,000,000
11. Others	126,000	126,000	126,000	126,000
12. Grains	-	-	-	800,000
13. Phosphates	250,000	1,500,000	1,500,000	1,500,000
TOTAL	3,131,817	5,344,171	5,350,795	6,157,620

TABLE 5.16 PESSIMISTIC FORECASTS FOR EXPORTS (TON)

ITEM	1985	1990	1995	2000
1. Dates	211,742	218,171	224,795	231,620
2. Fertilisers	376,332	825,089	1,000,000	1,000,000
8. Sulphur	902,686	1,266,064	1,500,000	1,500,000
9. Urea	606,440	1,000,000	1,000,000	1,000,000
11. Others	126,000	126,000	126,000	126,000
12. Grains	-	-	-	1,200,000
13. Phosphates	250,000	1,206,543	1,500,000	1,500,000
TOTAL	2,473,200	4,641,867	5,350,795	6,557,620

5.9 Cargo Classification and Ships Forecasting Model

In the light of the discussion provided in section 5.4, it is possible to determine the way that import and export commodities will be carried as maritime cargo, that is, to determine the volume of each class of cargo such as containerised cargo, general cargo, bulk cargo .. etc. The way these commodities were carried as maritime cargo in 1979 is shown in Table 5.17 together with the number of ships for each class of cargo and the average ship load. It was mentioned in Chapter 2 of this study that containerised traffic is expected to expand rapidly in future, for example, item 6 (drugs) is expected to be fully containerised by 1990 and 50 percent of item 14 (machinery) is also expected to be carried as containerised cargo. In 1979 both these items were carried as general cargo.

Since technological changes take the form of a swing to traffic specialisation, the cargo mix according to the Port Authority for the years 1985 onwards, is summarised in Table 5.18. From this table it is possible to obtain the amount of each class of cargo simply by adding the volume of commodities for each class as shown in Appendix C. The volume of each class of cargo for the three different forecasts is shown in Tables 5.21 to 5.23.

The final stage in forecasting is to convert the volume of each class of cargo into the number of ships carrying it through the port. The movement of cargo ships for the years 1974 - 1979 is shown in Table 5.19. Again, due to technological changes, larger ships are expected to come to the port especially bulk carriers, but due to the depth of the dredged channels, only vessels of a limited size carrying a load of just over 20,000 tonnes can be admitted. It is estimated again by the Port Authority that the average ship load for each class of cargo is as shown in Table 5.20.

TABLE 5.17 CARGO TYPE AND NO OF VESSELS COMING TO THE PORT 1979

		ITEM	TON	NO OF VESSELS	AV. SHIP LOAD (TON)
GENERAL CARGO	2.	Automobiles	16,747		
	3.	Coal	6,101		
	6.	Drugs	126,541		
	10.	Gunnies	13,385		
	11.	Iron	1,188,485		
	14.	Machinery	32,288		
	17.	Paints	1,613		
	19.	Sugar	340,254		
	20.	Tar	20,105		
	21.	Tea	29,490		
	22.	Timber	190,523		
	23.	Others	1,250,571		
		TOTAL	3,216,103	656	4,902
CONTAINER	1.	Alcohol	10,385		
	4.	Cotton	15,262		
	7.	Electric Goods	25,461		
	8.	Food	143,191		
	9.	Glassware	14,344		
	13.	Leather	3,683		
	16.	Paper	58,871		
	18.	Refrigerators	25,677		
		TOTAL	296,874	124	2,394
	5.	Bagged Cement	162,491	20	8,124
	12.	Bulk Grain	1,610,521	81	19,883
	15.	Bulk Oil	137,045	15	9,136
		GRAND TOTAL	5,423,034	896	6,052
		Fertiliser	146,709	25	5,868
		Sulphur	601,498	53	11,349
		Urea	276,286	39	7,084
				1,013	

TABLE 5.18 CARGO CLASS FOR EACH COMMODITY[1]

		ITEM	85	90	95	2000
IMPORTS	1.	Alcohol ...	C	C	C	C
	2.	Automobiles ...	G	G	G	AC
	3.	Coal ...	G	G	G	G
	4.	Cotton ...	C	C	C	C
	5.	Cement	BC	BC	BC	BC
	6.	Drugs ...	50%C,50%G	C	C	C
	7.	Electrical	C	C	C	C
	8.	Food	C	C	C	C
	9.	Glassware	C	C	C	C
	10.	Gunnies	G	G	G	G
	11.	Iron ...	G	G	G	G
	12.	Grains	BK	BK	BK	BK
	13.	Leather	C	C	C	C
	14.	Machinery	50%C,50%G	50%C,50%G	50%C,50%G	50%C,50%G
	15.	Oil	BK	BK	BK	BK
	16.	Paper	C	C	C	C
	17.	Paints	C	C	C	C
	18.	Refrigerators ..	C	C	C	C
	19.	Sugar	BK	BK	BK	BK
	20.	Tar	G	G	G	G
	21.	Tea	G	G	G	G
	22.	Timber	G	G	G	G
	23.	Others	75%G,25%C	50%G,50%C	50%G,50%C	50%G,50%C
EXPORTS	1.	Dates	G	85%G,15%C	70%G,30%C	50%G,50%C
	2.	Fertilisers	SB	SB	SB	SB
	8.	Sulphur	SB	SB	SB	SB
	9.	Urea	SB	SB	SB	SB
	11.	Others	75%G,25%C	50%G,50%C	50%G,50%C	50%G,50%C
	13.	Phosphates	SB	SB	SB	SB

[1] Iraqi Port Organisation

KEY: C - 100% container, AC - 100% auto-carrier, G - 100% general,
BC - 100% bagged cement, BK - 100% bulk grain, bulk oil or bulk sugar
SB - 100% solid bulk

TABLE 5.19 MARITIME TRANSPORT - MOVEMENT OF CARGO SHIPS[1]

	74	75	76	77	78	79
1. No. of Vessels Entered Iraqi Ports (No.)	749	828	891	984	1127	896[2]
2. No. of Vessels Sailed From Iraqi Ports (No.)	745	827	892	977	1136	893[2]
3. G.R.T. of Vessels Entered (Ton'000)	5909	8434	8861	11855	13841	11554
4. G.R.T. of Vessels Sailed (Ton '000)	5850	8305	9393	11872	13875	11341
5. Quantity of Imported Goods (Ton '000)	2715	3466	3430	3772	4191	5423
6. Quantity of Exported Goods (Ton '000)	882	1441	1279	964	897	1349
7. (5) + (6)	3592	4907	4709	4736	5088	6772
8. Av. G.R.T./Ship (3)÷(1)	7889	10186	9945	12047	12281	12895
9. Av. Load of Imp/Ship (5) ÷ (1)	3625	4185	3849	3833	3718	6052
10. Av. Load/G.R.T Ratio (5) ÷ (3)	0.459	0.411	0.387	0.318	0.302	0.469

AV. (10) = 0.391

[1]Iraqi Ports Organisation

[2]Except for Bulk Solid Carriers

TABLE 5.20 AVERAGE SHIP LOAD FOR EACH CLASS OF CARGO (TON)[1]

VESSEL CLASSIFICATION		85	90	95	2000
1. General		5,250	5,500	6,000	6,000
2. Container		2,500	3,000	3,000	3,000
3. Bulk Grain		20,000	20,000	20,000	20,000
4. Bulk Oil		10,000	15,000	20,000	20,000
5. Bulk Sugar		10,000	15,000	20,000	20,000
6. Auto-Carrier		-	-	-	1,500
7. Fertilisers	BULK CARRIER	10,000	20,000	20,000	20,000
8. Sulphur	BULK CARRIER	15,000	20,000	20,000	20,000
9. Urea	BULK CARRIER	10,000	20,000	20,000	20,000
10. Phosphates	BULK CARRIER	10,000	20,000	20,000	20,000

[1] Iraqi Ports Organisation

Having obtained the average ship load for each class of cargo it is possible to obtain the number of ships calling at the port at any future time period, before doing so, it must be mentioned that since exports are so much smaller than imports for the same cargo classes, it is possible for the same ships that carry the imports to the port to carry the exports away, once their loads have been discharged as can be seen from Table 5.19, that is, the number of vessels entering and sailing is almost equal, except for solid bulks (fertilisers, sulphur, urea and phosphates) where ships come empty to carry away those commodities.

The model for determining the number of ship calls at the port at any future time period will therefore be

For imports of each class of cargo

$$N_t = I_t / AL_t \qquad 5.14$$

where N_t = Number of ships in period t

I_t = Imports in period t

AL_t = Average load of ship in period t

t = Year

For exports of solid bulks

$$N_t = E_t / AL_t \qquad 5.15$$

where N_t, AL_t, and t are the same as in equation 5•6

E_t = Exports in period t

Using the above two models, the number of ships calling at the port for each class of cargo is obtained simply by dividing the volume of each cargo class by the average ship load of this class for different periods and is shown in Tables 5.21 to 5.23.

TABLE 5.21 CARGO CLASS BY WEIGHT AND NUMBER OF VESSELS (OPTIMISTIC FORECASTS)

CARGO CLASS (VESSEL CLASSIFICATION)	85		90		95		2000	
	TON	NO	TON	NO	TON	NO	TON	NO
GENERAL	5,344,501	1018	8,651,417	1573	16,554,872	2759	31,501,479	5251
CONTAINER	1,770,767	709	3,543,630	1182	6,647,860	2216	12,446,051	4149
BULK GRAIN	1,511,562	76	1,236,729	62	562,439	29	800,000[1]	40
BULK OIL	207,985	21	294,446	20	416,849	21	590,138	30
BULK SUGAR	420,689	43	502,065	34	599,182	30	715,085	36
AUTO-CARRIER	-	-	-	-	-	-	149,871	100
FERTILISERS	508,027	51	1,000,000	50	1,000,000	50	1,000,000	50
SULPHUR	1,125,050	75	1,500,000	75	1,500,000	75	1,500,000	75
UREA	910,998	92	1,000,000	50	1,000,000	50	1,000,000	50
PHOSPHATES	250,000	25	1,500,000	75	1,500,000	75	1,500,000	75
TOTAL		2110		3121		5305		9856

1 Exports

TABLE 5.22 CARGO CLASS BY WEIGHT AND NUMBER OF VESSELS (MOST LIKELY FORECASTS)

CARGO CLASS (VESSEL CLASSIFICATION)	85		90		95		2000	
	TON	NO	TON	NO	TON	NO	TON	NO
GENERAL	4,571,982	871	6,497,848	1182	10,890,015	1815	18,152,784	3026
CONTAINER	1,491,144	597	2,735,805	912	4,522,919	1508	7,511,947	2504
BULK GRAIN	1,478,460	74	1,164,653	59	437,921	22	1,000,000[1]	50
BULK OIL	203,371	21	282,583	19	392,647	20	545,581	28
BULK SUGAR	415,840	42	491,506	33	580,925	30	686,630	35
AUTO-CARRIER	-	-	-	-	-	-	149,871	100
FERTILISERS	438,070	44	1,000,000	50	1,000,000	50	1,000,000	50
SULPHUR	1,023,866	69	1,500,000	75	1,500,000	75	1,500,000	75
UREA	750,000	75	1,000,000	50	1,000,000	50	1,000,000	50
PHOSPHATES	250,000	25	1,500,000	75	1,500,000	75	1,500,000	75
TOTAL		1818		2455		3645		5993

[1] Exports

TABLE 5.23 CARGO CLASS BY WEIGHT AND NUMBER OF VESSELS (PESSIMISTIC FORECASTS)

CARGO CLASS (VESSEL CLASSIFICATION)	85		90		95		2000	
	TON	NO	TON	NO	TON	NO	TON	NO
GENERAL	3,897,100	743	4,854,093	883	7,112,023	1186	10,298,976	1717
CONTAINER	1,261,284	505	2,119,223	707	3,105,768	1036	3,568,304	1190
BULK GRAIN	1,445,678	73	1,093,957	55	316,966	16	1,200,000[1]	60
BULK OIL	198,844	20	271,157	19	369,767	19	504,240	26
BULK SUGAR	411,037	42	481,149	33	563,220	29	659,290	33
AUTO-CARRIER	-	-	-	-	-	-	149,871	100
FERTILISERS	376,332	38	825,089	42	1,000,000	50	1,000,000	50
SULPHUR	902,686	61	1,266,064	64	1,500,000	75	1,500,000	75
UREA	606,440	61	1,000,000	50	1,000,000	50	1,000,000	50
PHOSPHATES	250,000	25	1,206,543	61	1,500,000	75	1,500,000	75
TOTAL		1568		1914		2536		3376

[1] Exports

Having obtained the volume for each class of cargo and the number of ships calling at the port, the trends (in tonnes or ships against time) for each cargo class is plotted and is shown in figures 5.3 to 5.13.

In conclusion in this chapter, it must be said that the forecasts have been prepared on the best available information. Since the forecasts cover a long time range (up to the year 2000), additional information may be made available concerning the import and export items, economic growth rate and production, this is why three forecasts were made (pessimistic, most likely and optimistic) covering a wide range of variations in order to minimise the risk of deviations. For example, growth rates in GDP (where most of the items are influenced by this component) ranging from 8 per cent to 14 per cent were used, at present it is thought very unlikely that the growth rates will deviate from those figures, even if they do for some unseen reason presently, the same models will be used to update the forecasts.

The main aim of forecasting is to obtain the number of ships (for each class of cargo) passing through the port at different times into the future which provide the main input for the simulation model (Chapter 6) where the output of the three different forecasts is simulated for different port configurations, that is, a varying number of berths to measure the resulting congestion and hence enabling us to arrive at an optimum decision concerning the number of berths required to service the ships at any future time period.

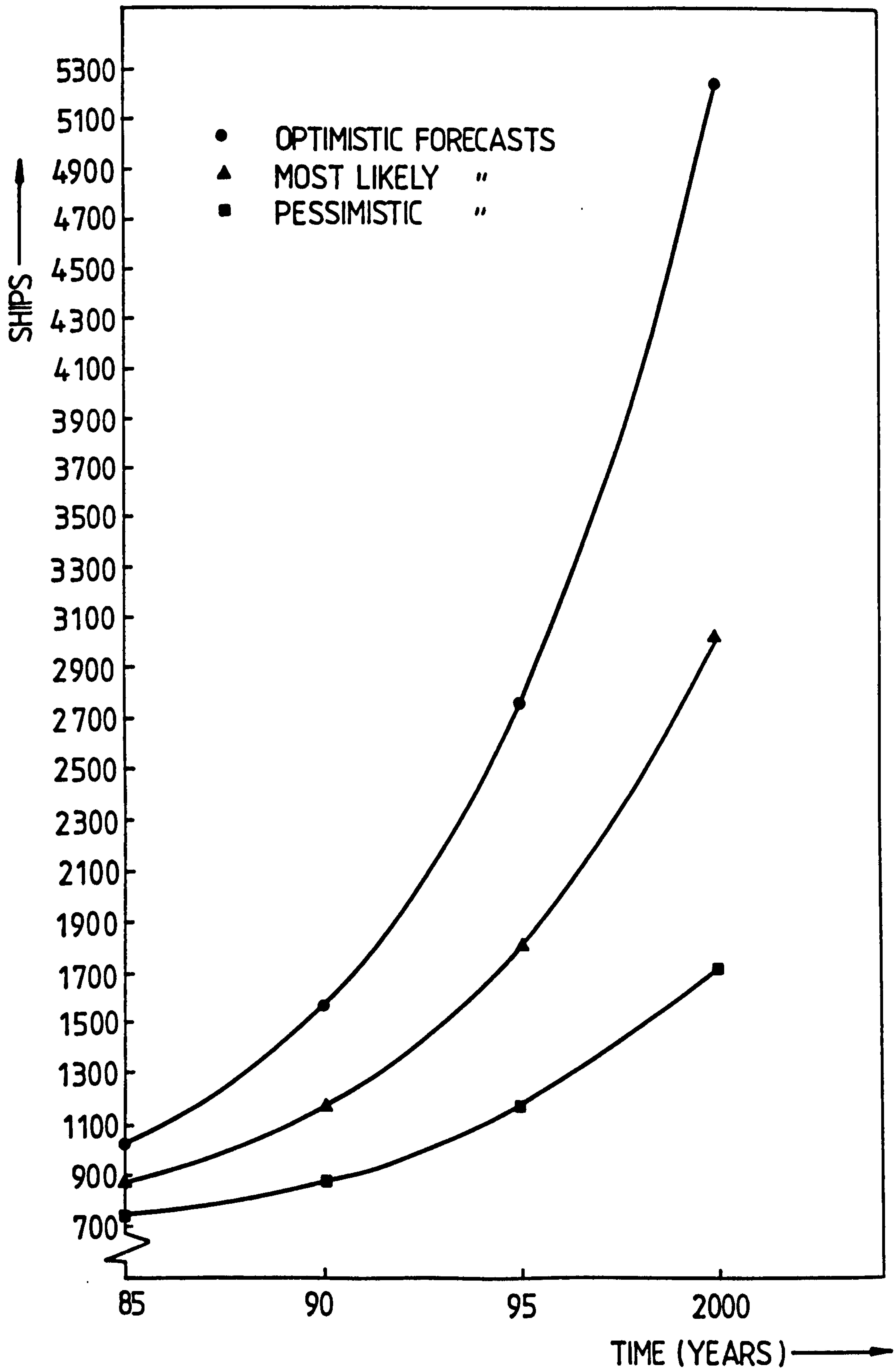


FIGURE 5-3 DEMAND (SHIPS) V. TIME (YEARS), GENERAL CARGO TRAFFIC

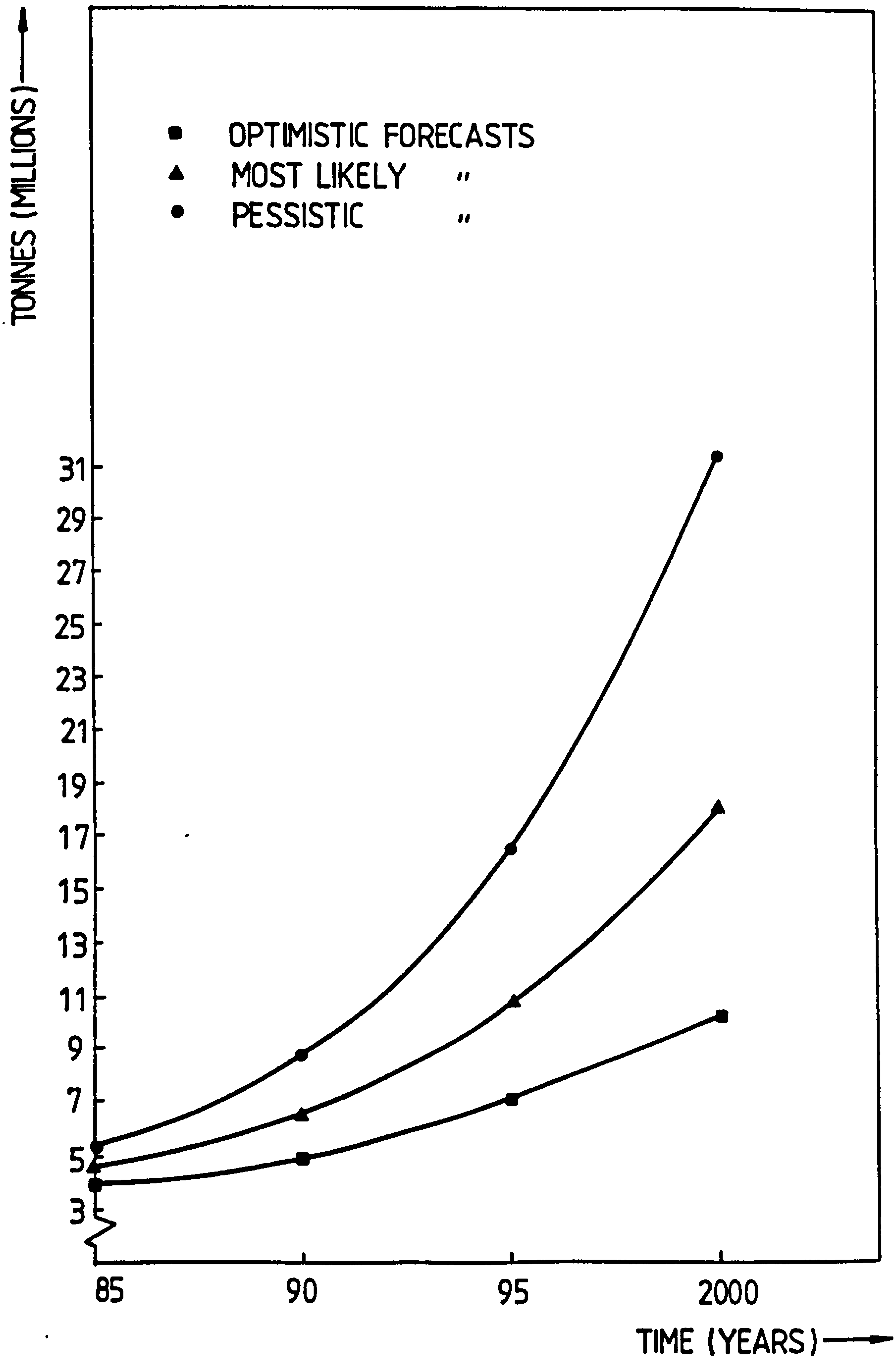


FIGURE 5-4 DEMAND (TONNES) V. TIME (YEARS), GENERAL CARGO TRAFFIC.

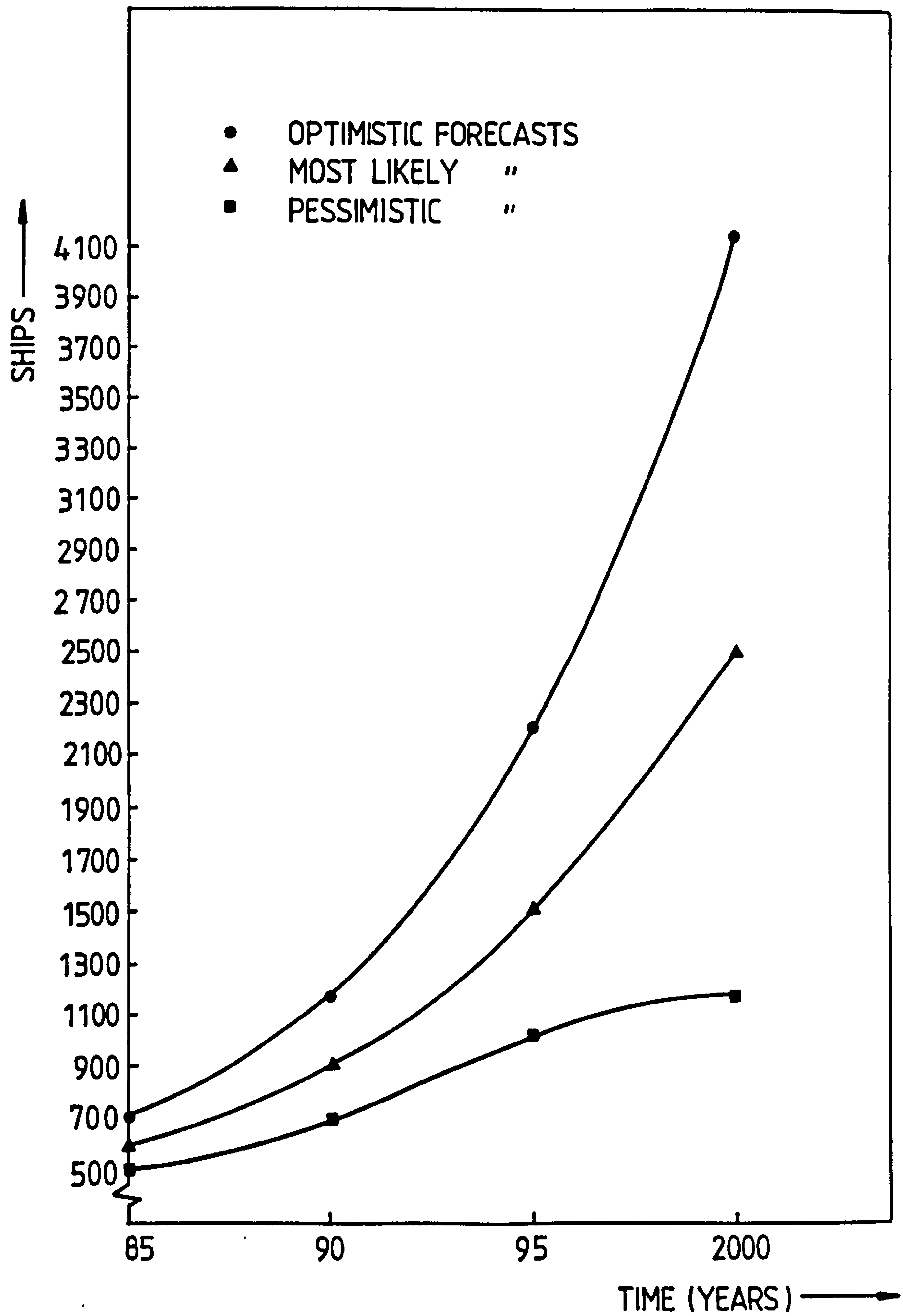


FIGURE 5 - 5 DEMAND (SHIPS) V. TIME (YEARS), CONTAINER TRAFFIC

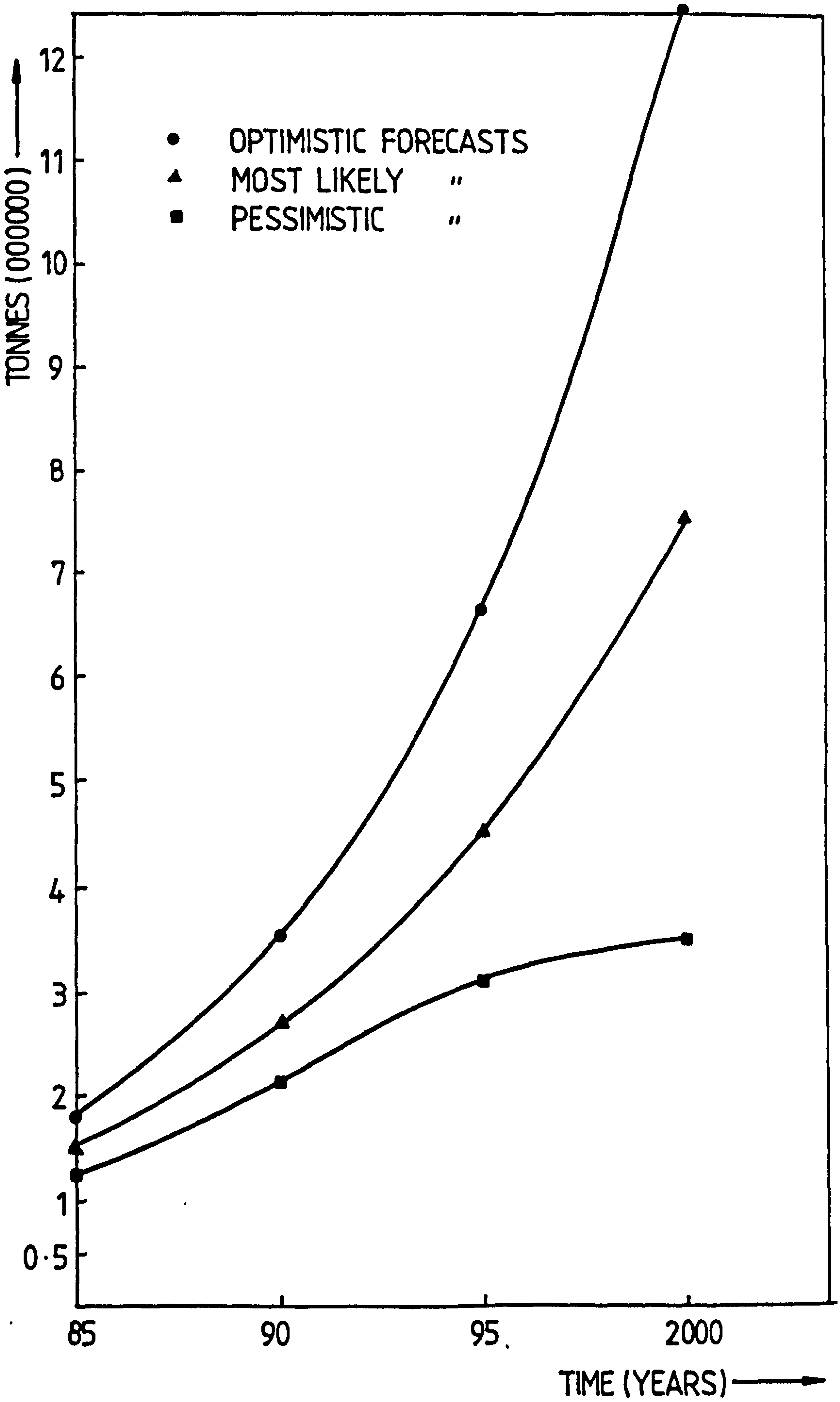


FIGURE 5-6 DEMAND (TONNES) V. TIME (YEARS), CONTAINER TRAFFIC .

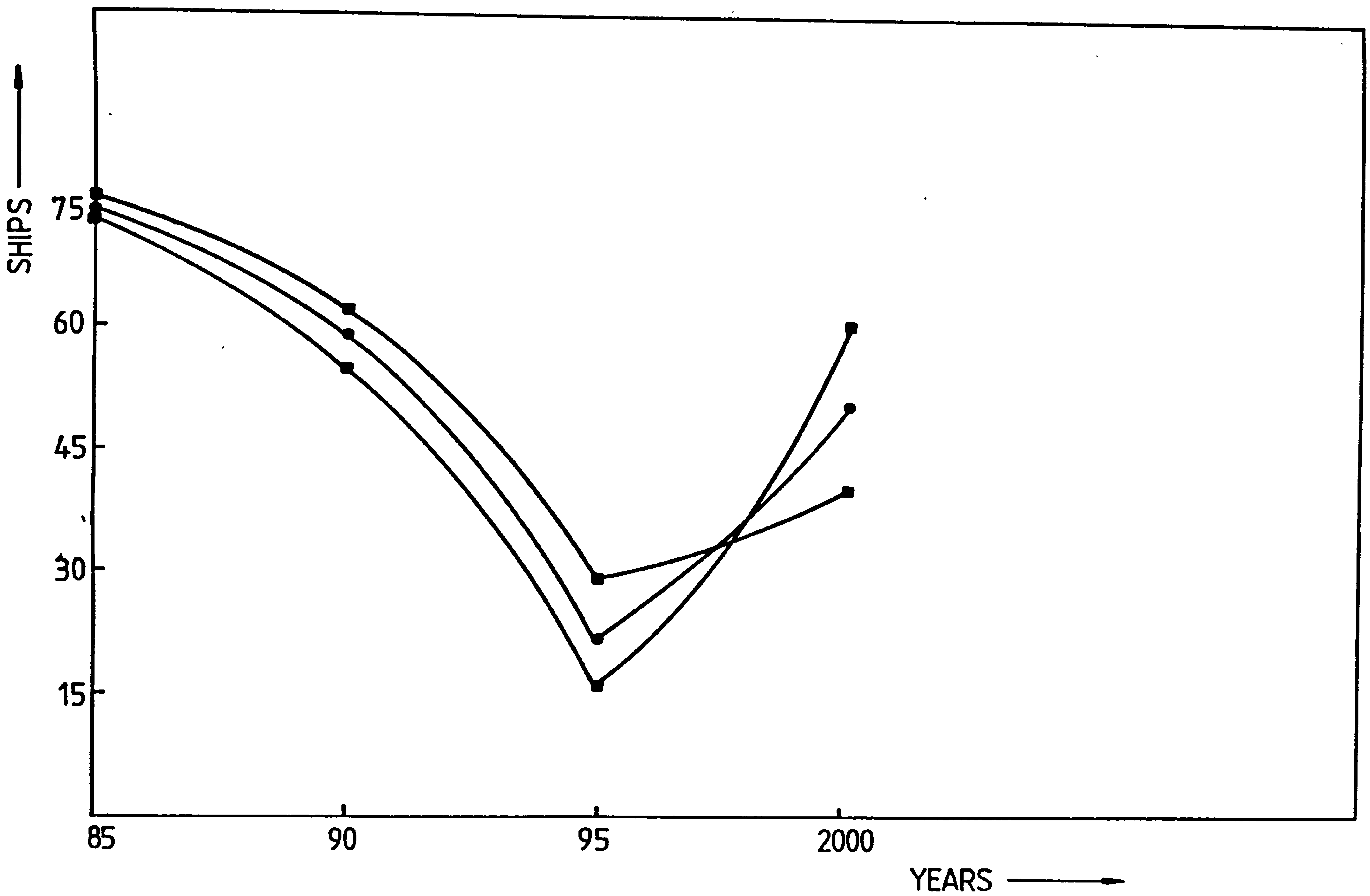
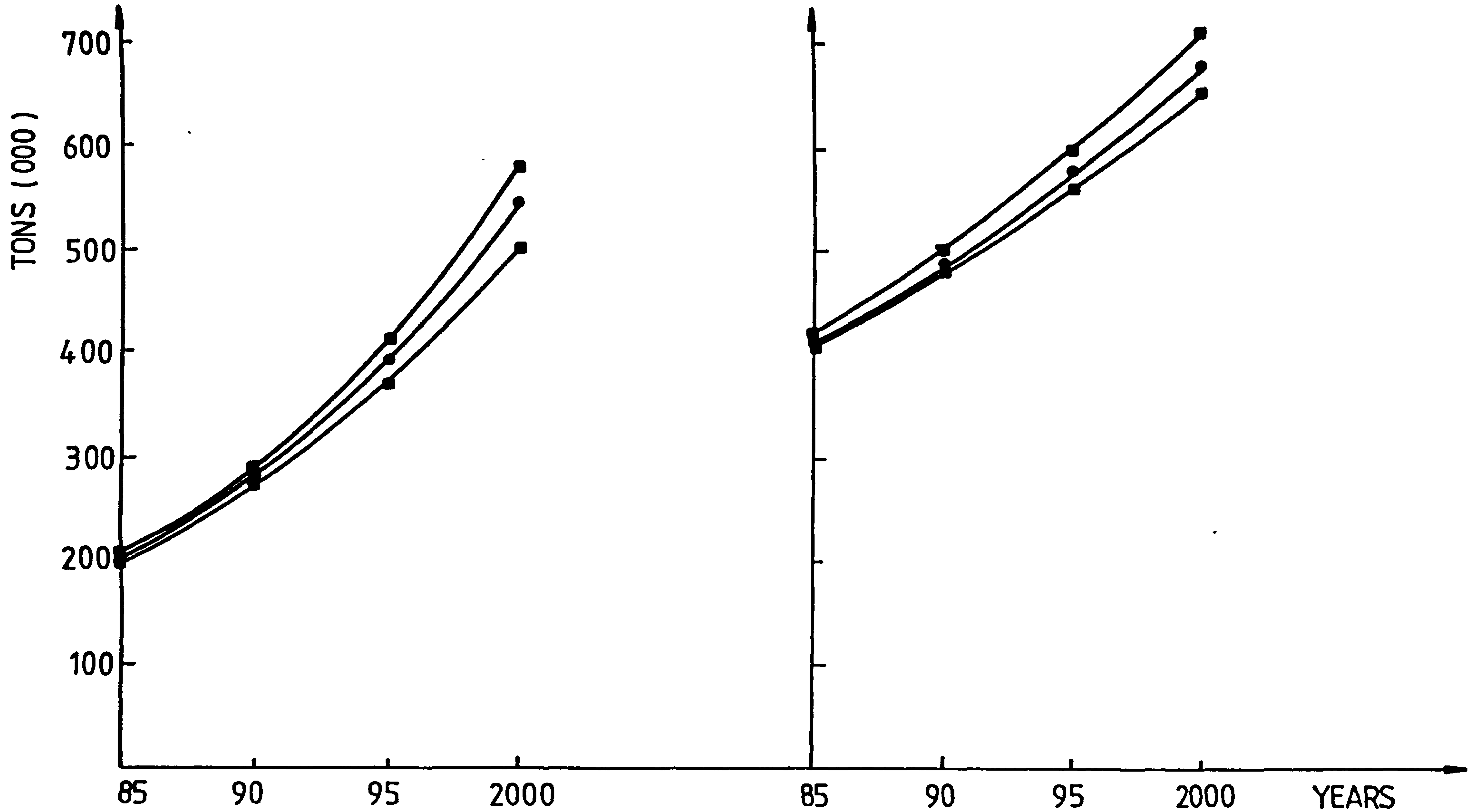


FIGURE 5 - 7 DEMAND (SHIPS) V. TIME (YEARS), GRAIN TRAFFIC PESSIMISTIC, MOST LIKELY AND OPTIMISTIC FORECASTS

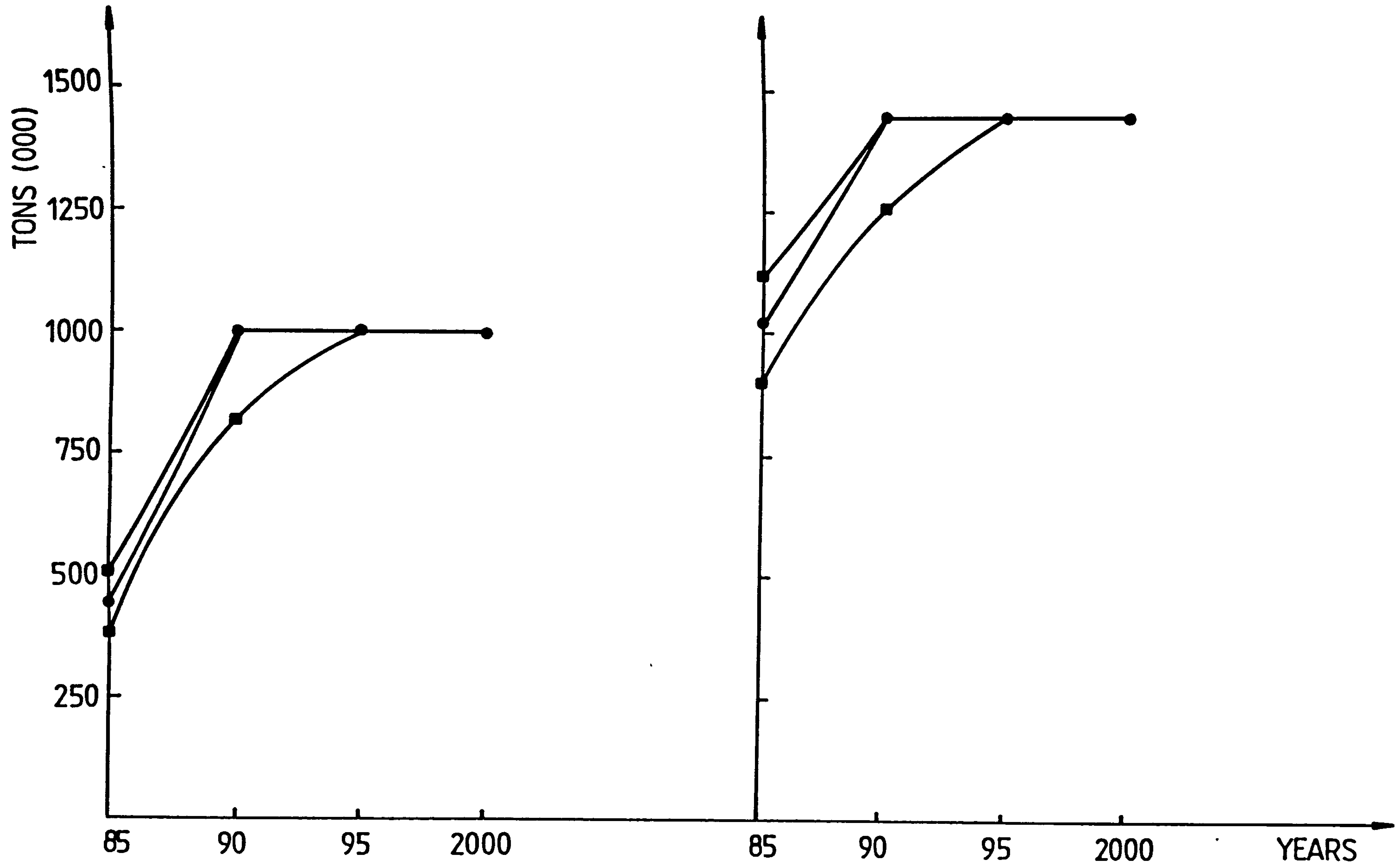


DEMAND (TONS) V. TIME (YEARS)

PESSIMISTIC, MOST LIKELY AND OPTIMISTIC FORECASTS

FIGURE 5 - 8 . OIL TRAFFIC

FIGURE 5 - 9 . SUGAR TRAFFIC

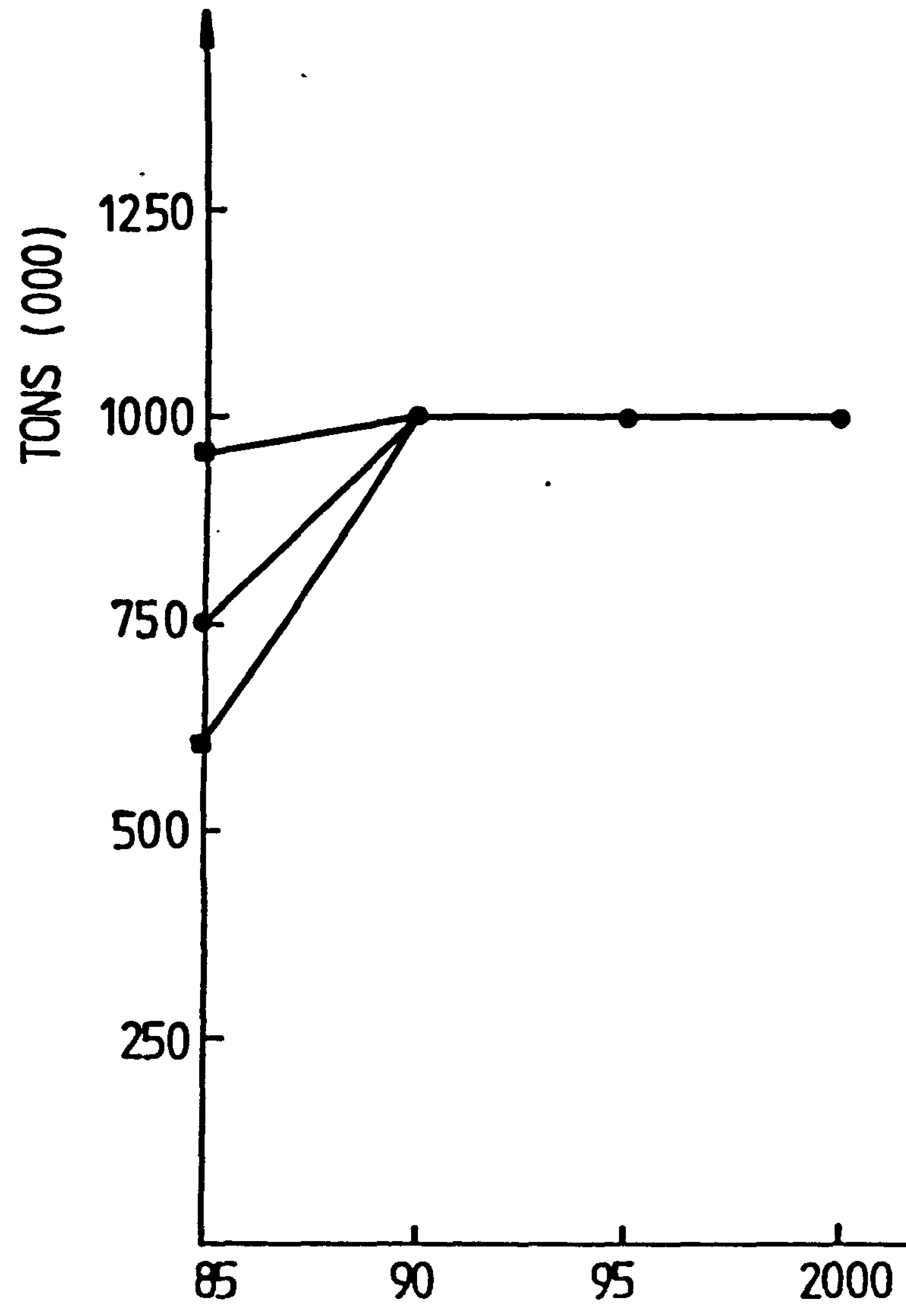


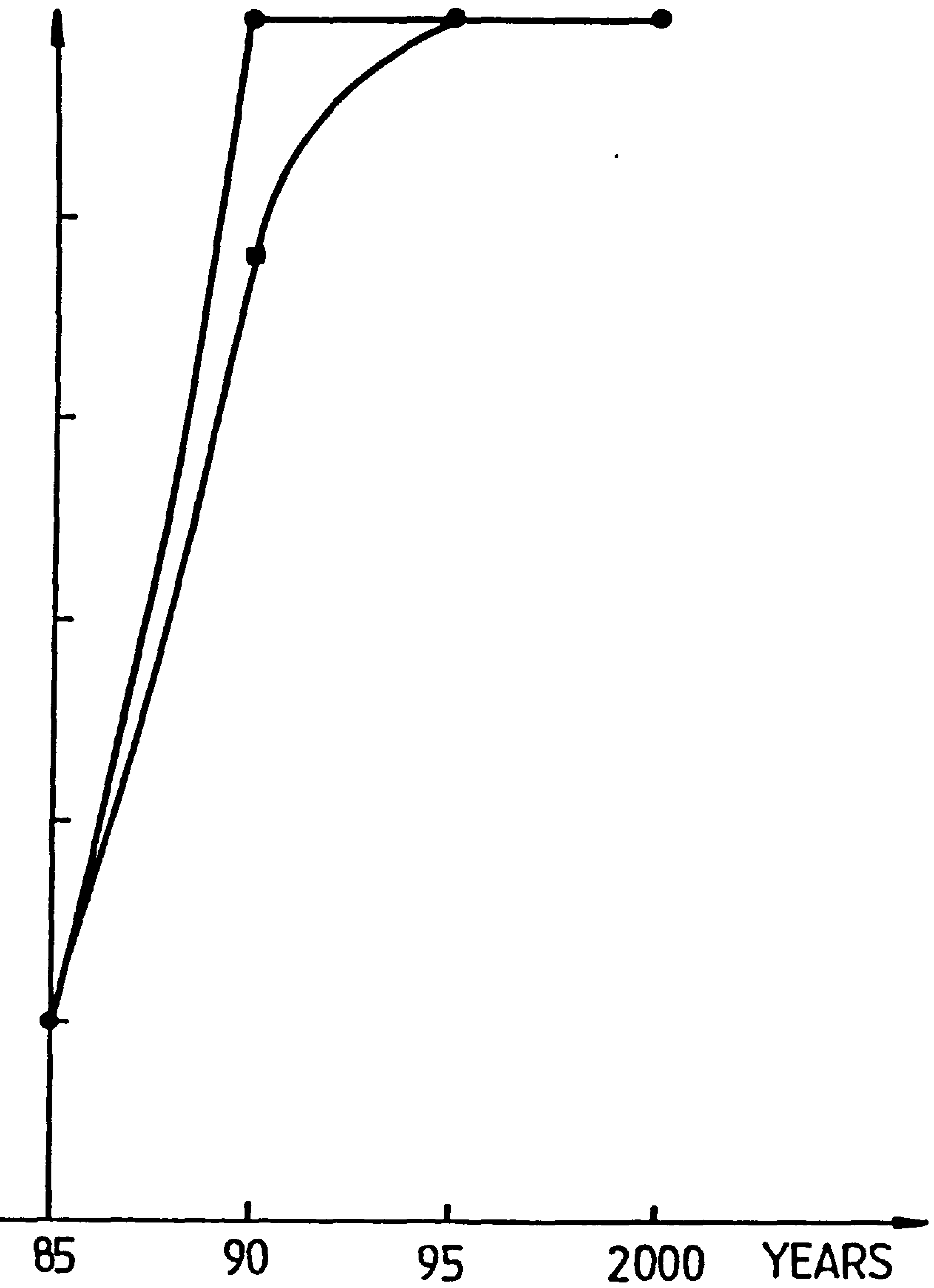
DEMAND (TONS) V. TIME (YEARS)

PESSIMISTIC, MOST LIKELY AND OPTIMISTIC FORECASTS

FIGURE 5 - 10 FERTILIZERS TRAFFIC

FIGURE 5 -11 SULPHUR TRAFFIC





DEMAND (TONS) V. TIME (YEARS)

PESSIMISTIC, MOST LIKELY AND OPTIMISTIC FORECASTS

FIGURE 5-12 UREA TRAFFIC

FIGURE 5 - 13 PHOSPHATE TRAFFIC

CHAPTER 6

PORT SIMULATION

6.1 Introduction

The aim of this chapter is to determine the waiting times and queue lengths of ships, and the idle times of berths resulting from the arrivals and departures of the different types of vessels through the ports. This will be achieved by simulating the stockastic pattern of arrivals of ships and the stochastic service times at the berths for different port configurations, that is, for an increasing number of berths for each class of cargo for different times into the future taking into consideration the constraints of the port stystem such as the effects of tides and shift times.

Having determined the forecasts for each type of cargo class and obtained the number of ships carrying it through the port, it is necessary to know at this stage what cargo and its amount is handled at each of the three ports together with capacity, specialisation and number of berths handling the required cargo. In 1979 Basra port handled a large portion of general cargo, bulk grain, vegetable oil and urea; Um Qasr port handled the rest of the general cargo, containerised cargo, cement and sulphur; while Khor Al Zubair port handled the chemical fertilisers. The actual amounts handled by each port in 1979 for each class of cargo is shown in Table 6.1 below.

From 1985 onwards the picture will change somehow since some types of cargo will not have to be imported anymore such as cement, new types of cargo have to be handled such as sugar, automobiles and phosphates, plus the fact that Khor Al Zubair (the Industrial Port) will deal only with fertilisers, sulphur, urea and phosphates. In addition to the above, there is no room for expansion in Basra port to cater for the increased volume of general cargo traffic, and hence the fifteen berths in the port cannot be increased necessitating the increased volume of general cargo traffic to be diverted to Um Qasr where most of the expansion in port capacity will take place in future years.

TABLE 6.1 AMOUNT OF CARGO (TONS) HANDLED BY EACH PORT IN 1979

CARGO CLASS	BASRA		UM QASR		KHOR AL ZUBAIR	
	IMPORTS	EXPORTS	IMPORTS	EXPORTS	IMPORTS	EXPORTS
1. General Cargo	2,422,512	204,277	793,591	106,370	-	-
2. Grains	1,610,521	-	-	-	-	-
3. Oils	137,045	-	-	-	-	-
4. Urea	-	276,286	-	-	-	-
5. Container	-	-	296,874	-	-	-
6. Cement	-	-	162,491	-	-	-
7. Sulphur	-	-	-	601,498	-	-
8. Fertilisers	-	-	-	-	-	146,709

TABLE 6.2 AMOUNT OF CARGO (TONS) HANDLED BY EACH PORT FOR 1985

CARGO CLASS	BASRA		UM QASR		KHOR AL ZUBAIR	
	IMPORTS	EXPORTS	IMPORTS	EXPORTS	IMPORTS	EXPORTS
1. General Cargo	[1]	306,242	[1]	-	-	-
2. Grains	1,478,460	-	-	-	-	-
3. Oils	203,371	-	-	-	-	-
4. Sugar	415,840	-	-	-	-	-
5. Containers	-	-	1,491,144	31,500	-	-
6. Automobiles	-	-	-	-	-	-
7. Fertilisers	-	-	-	-	-	438,070
8. Sulphur	-	-	-	-	-	1,023,866
9. Urea	-	-	-	-	-	750,000
10. Phosphates	-	-	-	-	-	250,000

[1] The amount handled by each port will be determined by simulating for different volumes in each period resulting in the best routing policy for the fifteen general cargo berths in Basra and an increasing number of berths in Um Qasr.

TABLE 6.3 AMOUNT OF CARGO (TONS) HANDLED BY EACH PORT IN 1990

CARGO CLASS	BASRA		UM QASR		KHOR AL ZUBAIR	
	IMPORTS	EXPORTS	IMPORTS	EXPORTS	IMPORTS	EXPORTS
1. General Cargo	[1]	248,445	[1]	-	-	-
2. Grains	1,164,653	-	-	-	-	-
3. Oils	282,583	-	-	-	-	-
4. Sugar	491,506	-	-	-	-	-
5. Containers	-	-	2,735,805	95,726	-	-
6. Automobiles	-	-	-	-	-	-
7. Fertilisers	-	-	-	-	-	1,000,000[2]
8. Sulphur	-	-	-	-	-	1,500,000[2]
9. Urea	-	-	-	-	-	1,000,000[2]
10. Phosphates	-	-	-	-	-	1,500,000[2]

[1] The amount handled by each port will be determined by simulating for different volumes in each period resulting in the best routing policy for the fifteen general cargo berths in Basra and an increasing number of berths in Um Qasr.

[2] The same amounts will be handled for the periods 1995 and 2000

TABLE 6.4 AMOUNT OF CARGO (TONS) HANDLED BY EACH PORT IN 1995

CARGO CLASS	BASRA		UM QASR	
HANDLED	IMPORTS	EXPORTS	IMPORTS	EXPORTS
1. General Cargo	[1]	220,356	[1]	-
2. Grains	437,921	-	-	-
3. Oils	392,647	-	-	-
4. Sugar	580,925	-	-	-
5. Containers	-	-	4,522,919	130,439
6. Automobiles	-	-	-	-

TABLE 6.5 AMOUNT OF CARGO (TONS) HANDLED BY EACH PORT IN 2000

CARGO CLASS	BASRA		UM QASR	
HANDLED	IMPORTS	EXPORTS	IMPORTS	EXPORTS
1. General Cargo	[1]	178,810	[1]	-
2. Grains	-	1,000,000	-	-
3. Oils	545,581	-	-	-
4. Sugar	686,630	-	-	-
5. Containers	-	-	7,511,947	178,810
6. Automobiles	-	-	149,871	-

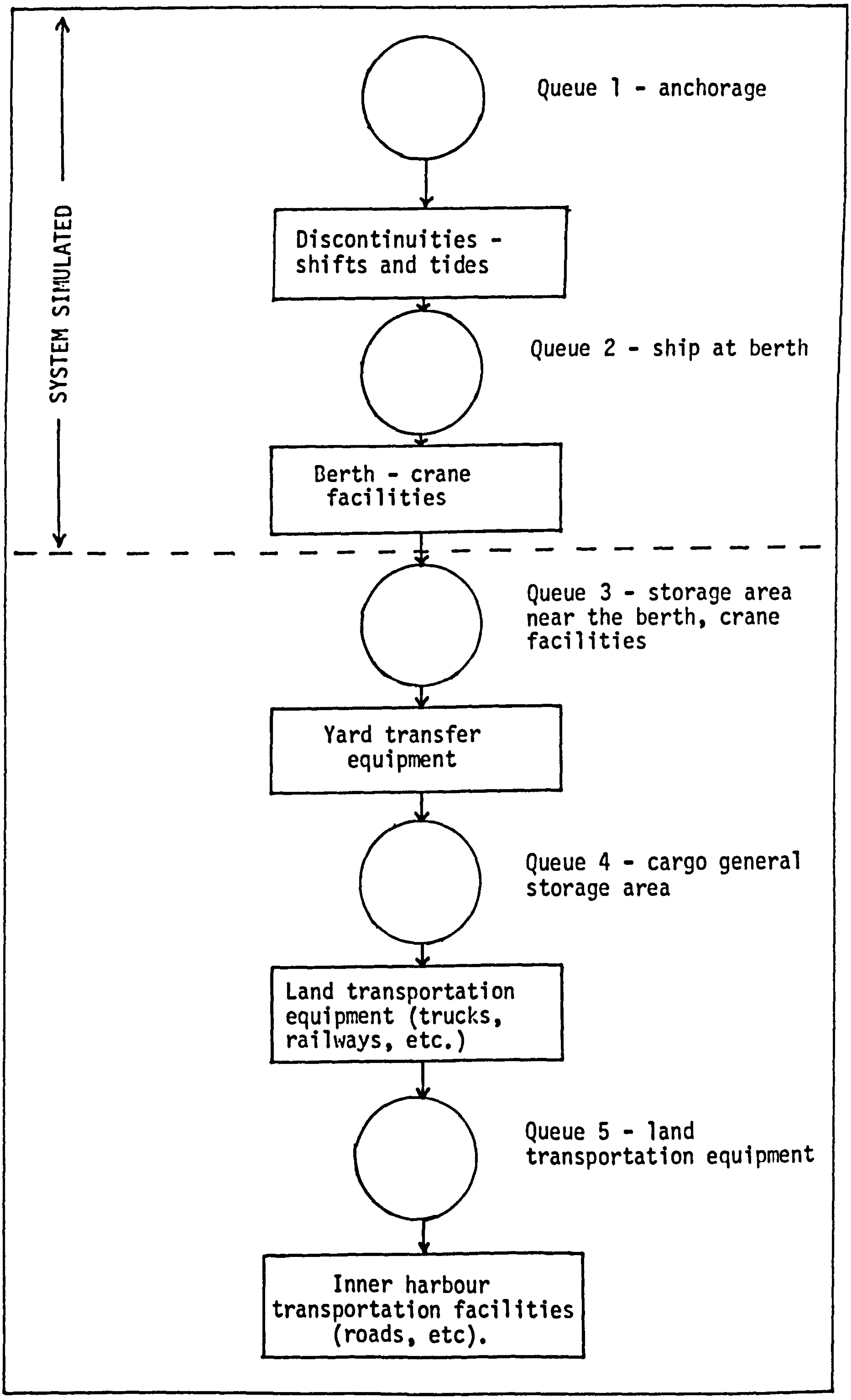
[1] The amount handled by each port will be determined by simulating for different volumes in each period resulting in the best routing policy for the fifteen general cargo berths in Basra and an increasing number of berths in Um Qasr.

Therefore from 1985 onwards, Basra port will handle a portion of general cargo imports (the amount of which will be determined in Chapter 8 by determining the best routing policy since it is shared with Um Qasr) plus all the general cargo exports, grains, oils and sugar, Um Qasr port will handle the rest of the general cargo imports, all the container traffic (imports and exports), and automobile carriers in the year 2000; and finally Khor Al Zubair port will handle fertilisers, sulphur, urea and phosphates (refer to Tables 5.21 to 5.23 of Chapter 5). The amounts handled by each port from 1985 onwards for each class of cargo is shown in Tables 6.2 to 6.5 for the most likely forecasts.

The number of berths, their capacity and specialisation for the year 1979 is shown in Table 2.2 of Chapter 2, while that for 1985 onwards has yet to be determined, except for the general cargo berths in Basra where they are constant and the number of ships (or amount of cargo) to be handled there is to be determined so the rest of the general cargo can be routed to Um Qasr and the number of berths required to handle it has to be determined. It must be mentioned here that while the grain ships were sharing two of the general cargo berths in 1979, additional grain berths will be provided from 1985 onwards, and each cargo class will be serviced by its group of berths only.

6.2 General Description

In Chapter 1, section 1.1, it was mentioned that this study will not consider in any detail the day-to-day requirements of operating the port, that is, the simulation model will not take account of the number of pilots, tugs ... etc., on the seawardside; nor the storage area and inland distribution system on the landside. The figure next page gives a schematic diagram of the total port system. The terms of reference of this study are enclosed within the dotted diagram. Berth capacity is the fundamental constraint on the port capacity, and whilst quay side facilities and warehousing are of unquestionable importance, they nonetheless are secondary to berth capacity and lie in the area of conventional port design and management. However, the implications for storage facility are considered in section 6.5.



Basic Structure of Cargo-Transportation System

Similarly, the landside transport facilities are outside the simulation model but in this case the implications for landside developments (in terms of vehicles, load capacities, etc.) are considered in section 6.6.

(Hansen 1972) makes the qualification that the landside transfer and storage of goods yields no significant delay in servicing ships. The quayside operations only will be simulated in this study which will include the following:-

1. The number of ships arriving at the port for each class of cargo,
2. The pattern of arrival of ships and their time of arrival,
3. Amount of time spent waiting for tides,
4. Amount of time spent for the next shift to start,
5. The time required for servicing the ships (unloading/loading) at the berths and the service pattern,
6. Time spent waiting for a vacant berth,
7. Total ship time in port,
8. Number of berths for each class of cargo,
9. Berth active and idle time.

As Basra, Um Qasr and Khor Al Zubair ports handle different types of cargo (see section 6.1), each port will be simulated as a multi-berth-multi-queue system. When ships arrive at the port they are admitted to the first vacant berth on a first-come-first-served basis. The time interval between successive arrivals is a stochastic variate with a known probability distribution and the service time for each berth is also a stochastic variate with each group of berths having its own probability distribution for service time.

When a ship arrives at the port, every berth (in each berth group) is checked to determine whether any of them is vacant at the moment. If all berths are occupied, then waiting time occurs until one berth becomes free. When a berth becomes vacant before another ship arrives at the port, idle time occurs until a ship arrives and enters the vacant berth.

It was mentioned in Chapter 4 of this study that the ports operate during the day only, from 6.00am - 6.00pm for two shifts, this implies that ships arriving or departing outside those hours have to wait for the next shift to be serviced, provided that there is a vacant berth. It was also mentioned that the ports are tidal, that is, in addition to waiting for the next shift to start, ships can only approach and leave the berths during the tides which occur approximately every six hours and last for approximately the same period. Hence ships have to wait for shifts, tides and a vacant berth before being able to dock at a berth to unload/load their cargo. This process is illustrated in Figure 6.1

The port simulated as a multiberth-multi-queue system is described by specifying the following:-

- number of ships for each type of cargo and their pattern of arrival

- number of berths for each type of cargo, their capacity and the pattern of service time.

- shift constraints.

- tidal constraints.

In Section 6.3 a sample of the input data submitted to the model is provided.

The results of the simulation model provide detailed tables of what happens to each ship from the time it enters the system to the time it leaves it, also provided is a summary of results such as average

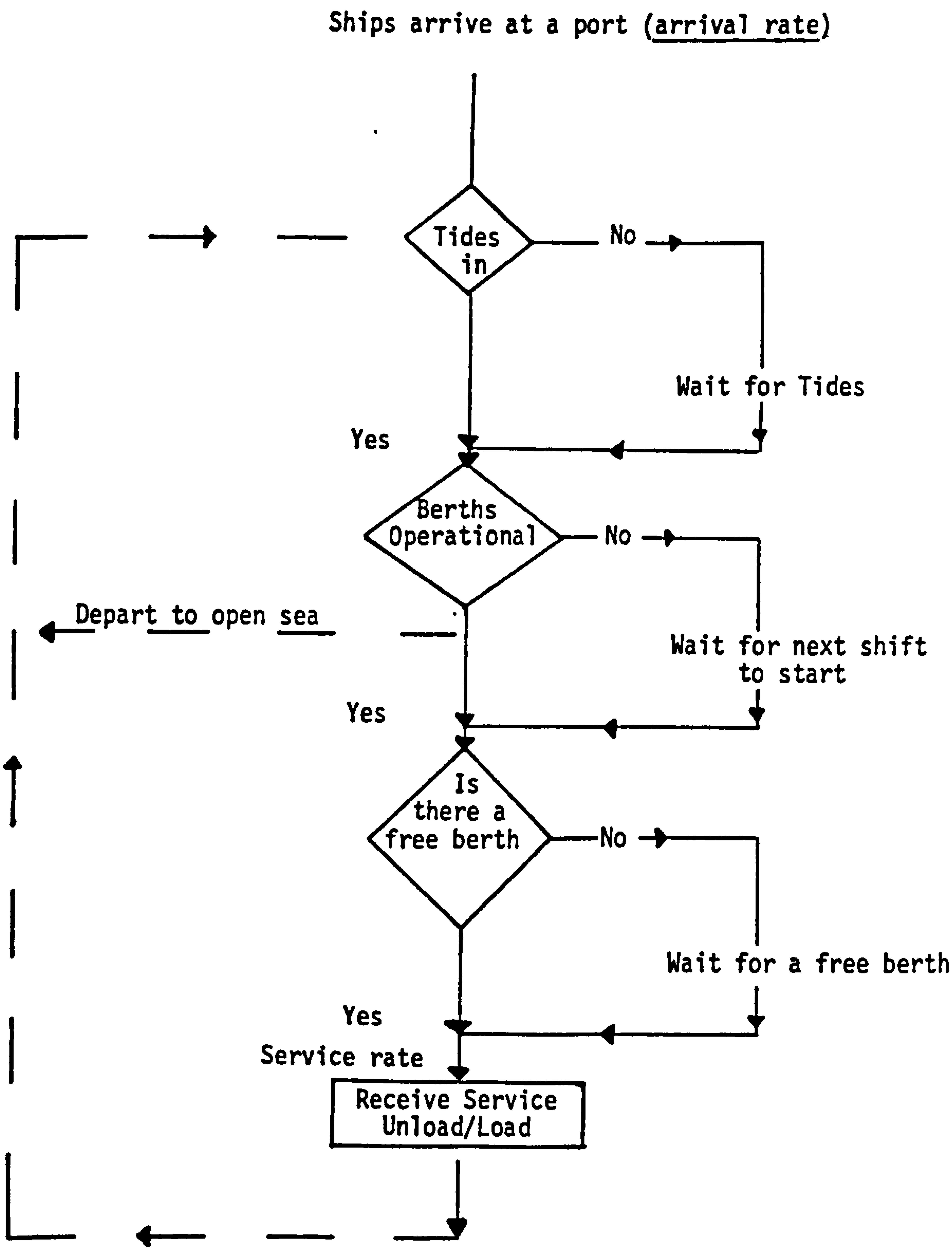


FIGURE 6.1 DIAGRAM SHOWING THE ARRIVAL AND DEPARTURE OF SHIPS THROUGH A PORT

waiting time per ship, waiting time distributions, percentage idle time for each berth group, idle time distributions, maximum queue length of ships and queue length distribution as will be seen later in the chapter.

Each ship type has two associated random variables; interarrival and service time. Each ship arrival is generated from the interarrival distribution and the service time is generated from the service distribution. In almost all cases, port activity is studied under steady-state conditions (see Section 4.3.2 of Chapter 4), however, the simulation model starts in an empty state and does not immediately represent a state of equilibrium. The model allows specfication of a time period (run-in-time) to approach the steady-state during which no performance of statistics are collected as will be seen later in Section 6.4.

6.3 Data Input

The number of ships for each type of cargo passing through the port together with the amount of cargo carried is determined in Chapter 4 by forecasting past data (see Tables 5.19 to 5.21). The pattern of interarrival and service time (interarrival and service distributions) are determined from historical data; in the Iraqi ports the inter-arrival distribution is negative exponential and the service distrib-ution is normal.

The number of berths and their capacity for the year 1979 is obtained from the Port Authority, while the number of berths for the years 1985 onwards has to be determined through simulation and later by investment appraisal.

The above is the basic input required for the simulation model and the input data as it stands in 1979 is shown in Table 6.6 and for the most likely forecasts for 1985 is shown in Table 6.7 which is similar to Table 6.6 except that the number of ships for general cargo at Basra port and Um Qasr port being a variable and also the number of berths at all other berth groups of the three ports being a variable that will be determined in Chapter 8 of this study.

TABLE 6.6 INPUT DATA FOR THE PORTS AS IT WAS IN 1979[1]

CARGO CLASS	QUANTITY SERVICED (Ton)	AVERAGE SHIP LOAD (Ton)	NUMBER OF SHIPS ARRIVING	NUMBER OF BERTHS	BERTH CAPACITY PER YEAR	MEAN SERVICE TIME PER SHIP μ (Hour)	STANDARD DEVIATION σ (Hour)
BASRA PORT 1979							
1. G.C.	2,626,789	5,350	491	15	300,000	156	40
2. Grain	1,610,521	19,883	81	2	400,000	435	100
3. Oil	137,045	9,136	15	1	400,000	200	40
4. Urea	276,286	7,084	39	1	400,000	155	34
UM QASR PORT 1979							
1. G.C.	899,961	5,454	165	4	300,000	159	36
2. Container	296,874	2,394	124	1	500,000	42	7
3. Cement	162,491	8,125	20	1	300,000	237	43
4. Sulphur	601,498	4,349	53	3	300,000	331	54
KHOR AL ZUBAIR PORT 1979							
1. Fertiliser	146,709	5,868	25	1	550,000	94	24

[1] Iraqi Ports Authority

Input data tables for the years 1979, 1985, 1990 and 2000 for different forecasts and shifts together with the simulation results are shown in Tables 6.11 to 6.39.

The data obtained from the Port Authority for the year 1979 and shown in Table 6.6 is explained below.

The column headed 'Quantity Serviced' is simply the sum of imports and exports (where applicable) such as general cargo for Basra and Um Qasr.

The column headed 'Average Ship Load' is the result of dividing the quantity serviced by the number of ships carrying the cargo eg. for general cargo in Basra the result is 2626789/491 = 5350.

The column headed 'Number of Ships Arriving' was obtained from the Port Authorities, and so were the data in columns, 'Number of Berths', 'Berth Capacity PER YEAR' and the 'STANDARD DEVIATION'.

As for the column headed 'Mean Service Time per Ship', it was obtained as follows:-

$$\text{Mean Service Time per Ship} = \left(\frac{\text{Average Shipload}}{\text{Berth Capacity per hour}}\right) \times 2^{(1)} \qquad 6.1$$

Berth Capacity per hour = Berth capacity/year ÷ number of working days per year ÷ number of working hours per day. 6.2

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(1) It can be seen that the average ship load/berth capacity in equation 6.1 is multiplied by 2 to obtain the mean service time per ship, this is because the berths operate for 12 hours a day and the time taken to service a ship is almost doubled since it has to wait for another 12 hours for the next shift to start in the morning.

TABLE 6.7 INPUT DATA FOR THE PORTS FOR 1985, MOST LIKELY FORECASTS

CARGO CLASS	QUANTITY SERVICED	AVERAGE SHIP LOAD	NUMBER OF SHIPS ARRIVING	NUMBER OF BERTHS	BERTH CAPACITY PER YEAR	MEAN SERVICE TIME PER SHIP μ	STANDARD DEVIATION σ
BASRA PORT 1985							
1 G.C	3,823,742	5,750	670	15	300,000	169	43
2 Grain	1,478,460	19,979	74	2	400,000	438	100
3 Oil	203,371	9,684	21	1	400,000	212	42
4 Sugar	415,840	9,901	42	1	400,000	217	43
UM QASR PORT 1985							
1.G.C	1,058,842	5,246	201	4	300,000	153	35
2 Container	1,522,644	2,550	597	3	500,000	45	7
KHOR AL ZUBAIR PORT 1985							
1 Fertiliser	438,070	9,956	44	1	550,000	159	40
2 Sulphur	1,023,866	14,838	69	2	550,000	236	38
3 Urea	750,000	10,000	75	2	550,000	159	35
4 Phosphates	250,000	10,000	25	1	550,000	159	26

TABLE 6.8 MEAN SERVICE TIME AND STANDARD DEVIATION

BASRA PORT			
CARGO TYPE	μ	σ	σ/μ
1. G.C	156	40	0.2564
2. Grain	435	100	0.2299
3. Oil	200	40	0.2000
4. Urea	155	34	0.2193
UM QASR PORT			
1. G.C	159	36	0.2264
2. Containers	42	7	0.1666
3. Cement	237	43	0.1814
4. Sulphur	331	54	0.1631
KHOR AL ZUBAIR PORT			
1. Fertilisers	94	24	0.2553

For example, the mean service time for a general cargo ship at Basra port would be obtained as follows:-

using equation 6.2, the berth capacity per hour = 300000 $\div$ 365 $\div$ 12 = 68.5

using equation 6.1, μ = (5350 $\div$ 68.5) x 2 = 156

The mean service time for all other ship types is obtained in the same way.

The standard deviation σ for the years 1985 onwards is based on the standard deviation of 1979 data. In 1979 the value σ/μ is worked out in Table 6.8.

Since sugar and phosphates are new types of cargo and their standard deviations are not available yet, it is recommended by the Port Authority to assume that their standard deviations will be similar to oil and sulphur respectively.

In working out σ for any type of ship for 1985 onwards, e.g. σ for G.C. in Basra in 1985 = 0.2564 x 169 = 43, σ for containers in Um Qasr in 1985 = 0.1666 x 45 = 7, and the same is done for each ship type for any future year.

6.4 Model Construction and Model Operation

In stochastic simulation the system usually starts in any empty state, that is, there are no ships in the system and all the berths are free. The system does not immediately represent a state of equilibrium and as mentioned earlier, a run-in-time must be allowed (during which no performance of statistics are collected) so that the system can reach stability. In this model a run-in-time of one year is allowed, for example, if we are simulating Khor Al Zubair port in 1985 where the number of ship arrivals per year is 213, a run-in-time of another 213 ships is allowed, making the total number of ships to be simulated 426 or two years, where the first year simulation is ignored.

Having decided on the total simulation time (or total number of ships to be simulated), the next step is to calculate an arrival time for each ship. This is done through using the interarrival distribution which is negative exponential as follows:-

Time interval between arrivals = $-\lambda\ \ell n(R)$[1]

where λ = the mean time between successive arrivals
= 365 (days/year) x 24 (hours/day) ÷ number of ships arriving per year for each class of cargo (determined by the forecasts).

R is a random number (0-1)

In the model this is done using a subroutine (PROCINTERV) as will be illustrated later by an example.

Since more than one type of ship is arriving at the port, the earliest of these is determined, that is, type of ship, its day and hour of arrival is worked out. The ship can proceed to a vacant berth to unload/load its cargo if the shifts and tides are on, otherwise, it has to wait for the next shift to start and for the tides before docking at a berth. Hence the next step is to calculate the time delay due to shifts and tides which is done in the model by using a subroutine (PROCDELAY) as will be illustrated by an example.

So far the type of ship, day and hour of its arrival and the time delay due to shifts and tides has been determined. Since the system starts in an empty state in the simulation, that is, all berths are free to start with, the ship can now proceed and enter any of the free berths to be serviced. The time the ship enters the berth is simply its arrival time plus the time delay due to shifts and tides (if any).

---

1 See Naylor et al 1968

Now that the ship is at berth awaiting service, the time taken to service the ship should be worked out. In the model this is done by using the service distribution which is normal as follows:-

$$\text{Service time} = \sigma \times \left(\sum_{i=1}^{12} R_i - 6 \right) + \mu^{(1)}$$

where σ is the standard deviation

R is a random number (0-1)

and μ is the mean service time

which in the model is done using a subroutine (PROCNORMAL) as will be illustrated in the example.

As more and more ships arrive at the port and occupy the vacant berths, all the berths might become occupied forcing the ships to wait for an empty berth. Hence the time the first berth will become empty should be determined, in other words the time the ship waits for an empty berth should be determined. In the model this is done using a subroutine (PROCMINDELAY) which calculates the berth that gives minimum delay to the waiting ships as will be illustrated later in the example.

As ships wait for an empty berth and due to the random pattern of arrival and service time, a queue of ships might form which gets bigger as more ships arrive and more berths get occupied, and smaller as more berths become available. To determine the length of the queue forming during the simulation yet another subroutine is used in the model (PROCQSIZE) to determine the queue size as will be illustrated in the example.

At this stage we know the berth number and we must calculate the time the ship leaves this berth. The time the ship leaves its berth is simply

---

1 See Naylor et al 1968

Time of arrival + Time delay due to tides and shifts + minimum delay for a free berth + service time + (time delay due to shifts and tides).

In the model the time delay due to shifts and tides when the ship has been serviced and wants to depart is added to the service time since the berth is being kept occupied by the ship.

Now it is possible to calculate the total waiting time for the ship, which is the time it had to wait for a free berth plus the time it had to wait for shifts and tides.

The same procedure is now repeated all over again to calculate the next arrival ... etc. until all the ships arriving have been simulated where the simulation stops. Having simulated all the arrivals in that particular year, the model then calculates the average waiting time per ship and the percentage idle time for each group of berths as follows:-

Average waiting time = Σ waiting time/number of ships arriving
Percentage idle time = $\Sigma \left[(\text{idle time})/(\text{total simulation time})\right] \times 100$

The above procedure is illustrated in Figure 6.2, while the full flow chart, the program for Basra port (1979) where grain ships share the general cargo berths together with the output are shown in Appendices D and E respectively.

To illustrate the above procedure, one of the simulations is used (Khor Al Zubair port 1985). In order to enable the reader to understand the model, the variables used in the program, the computer program and the simulation output for Khor Al Zubair port 1985 is shown in the next few pages.

It can be seen from Table 6.7 for the above port that the number of ships arriving in that year is 44 + 69 + 75 + 25 = 213. Since a run-in-time of another year is allowed to reach the steady state, then the total number of ships to be simulated is 213 + 213 = 426,

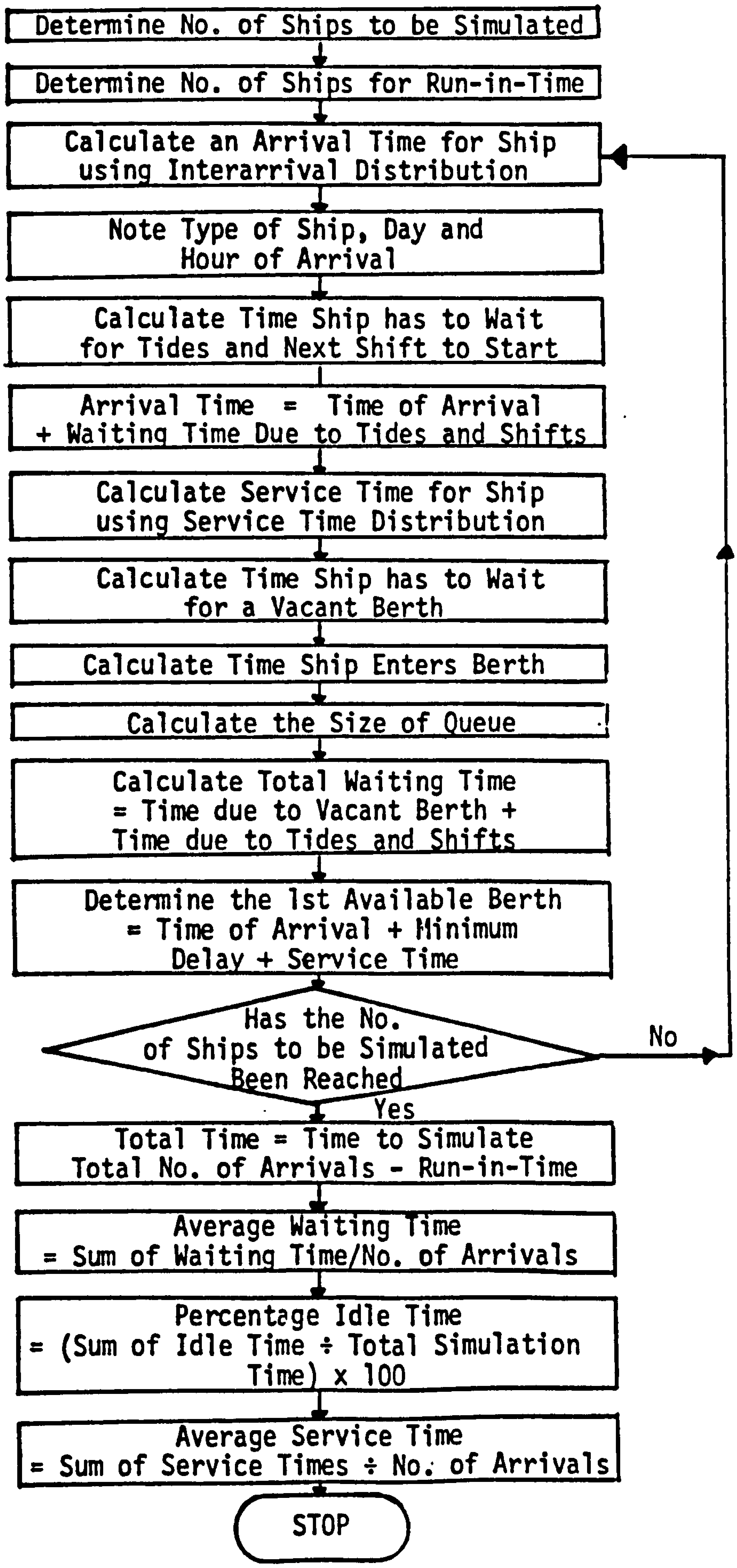


FIGURE 6.2 MODEL OPERATION

this is shown in line 20 of the program. The rest of the data, namely, number of ships arriving per year for each class of cargo, number of berths simulated, mean service time and the standard deviation is shown in lines 50-80 of the program where the data is read into the program.

In order to be able to follow the main features of the model, it is best to refer to the first page of the output where only one type (2) is considered to illustrate the operation of the model. The mean interarrival time is worked out in line 200 of the program and an arrival time is generated using PROCINTERV (lines 850-880 of the program) which gives us the first arrival of type 2 ships (line number 1 of the output), the next arrival of this type being in line 2 of the output ... etc. The first arrival as can be seen from the output is at day 19, hour 0 (i.e. 19 x 24 = 456 hours), and the first ten arrivals are shown in Table 6.9 below.

Table 6.9 CALCULATION OF WAITING TIME DUE TO SHIFTS AND TIDES

	TYPE	DAY	HR	ARRIV	TIDE 1	2	3	4	WAITING DUE TO SHIFTS		WAITING DUE TO TIDES		TOTAL TIDE
1	2	19	0	456	20	2	8	14	6	+	0	=	6
2	2	31	12	756	8	14	20	2	0	+	2	=	2
3	2	41	13	997	18	24	6	12	0	+	0	=	0
4	2	48	5	1157	1	7	13	19	1	+	1	=	2
5	2	55	13	1333	8	14	20	2	0	+	1	=	1
6	2	56	4	1348	9	15	21	3	2	+	0	=	2
7	2	59	5	1421	12	18	24	6	1	+	0	=	1
8	2	66	5	1589	19	1	7	13	1	+	0	=	1
9	2	72	3	1731	1	7	13	19	3	+	1	=	4
10	2	72	21	1749	1	7	13	19	9	+	1	=	10

Ships cannot enter the berths between the hours 6.00pm and 6.00am (the ports are not operational), nor can they enter between tides 1 and 2 and tides 3 and 4 (there are no tides).

Every new day the tides shift by 1 hour, that is, at day 19 hour 0 TIDE 1 starts at hour 20, TIDE 2 at 20 + 6 = 26, ie, hour 2, TIDE 3 at 2 + 6 = 8 and TIDE 4 at 8 + 6 = 14, this is shown in line 1 of Table 6.9. At day 31 hour 12

TIDE 1 = 31 - 24 + 1 = 8
TIDE 2 = 8 + 6 = 14
TIDE 3 = 14 + 6 = 20
TIDE 4 = 20 = 6 = 26 ie. hour 2, this is shown in line 2 of Table 6.9. The same procedure is adopted in calculating TIDE 1, 2, 3 and 4 and they are all shown in Table 6.9.

In order to calculate the time delay due to shifts, the time arrival of the ship is checked, if it is outside the hours 6.00am - 6.00pm the time delay is worked out as follows (see Table 6.9):-

Line 1	arrival is at hour 0	
	waiting time due to shifts	= 6.00am - 0 = 6
Line 2	" " " " "	= 0
Line 3	" " " " "	= 0
Line 4	" " " " "	= 6 - 5 = 1
Line 5	" " " " "	= 0
Line 6	" " " " "	= 6 - 4 = 2
Line 7	" " " " "	= 6 - 5 = 1
Line 8	" " " " "	= 6 - 5 = 1
Line 9	" " " " "	= 6 - 3 = 3
Line 10	" " " " "	=30 -21 = 9

In order to calculate the waiting time due to tides, the time brought forward (after adding time delay due to shifts) is checked and the waiting time due to tides is worked out as follows (see Table 6.9):-

Line 1 arrival time brought to 6.00 a.m., the tides are on between 2.00 a.m. - 8.00 a.m.
∴ waiting time due to tides = 0

Line 2	= 14 - 12 = 2
Line 3	= 0
Line 4	= 7 - 6 = 1
Line 5	= 14 - 13 = 1
Line 6	= 0
Line 7	= 0
Line 8	= 0
Line 9	= 7 - 6 = 1
Line 10	= 7 - 6 = 1

and the total waiting time due to shifts and tides (TIDE) is obtained by adding both delays as shown in Table 6.9.

The next step is to calculate the time taken to service the ship which is worked out in line 360 of the program and a service time is generated using PROCNORMAL (lines 1010-1050 of the program), the service time generated is tabulated in column 8 of Table 6.10.

Column 1 in Table 6.10 is obtained by using PROCINTERV
Column 2 in Table 6.10 is obtained by using PROCDELAY as shown earlier,
Column 8 in Table 6.10 is obtained by using PROCNORMAL

To work out the number of berths being used (if more than 1, column 3 in Table 6.10) and the time for columns 4, 5, 6, 7, 9 and 10; PROCMINDELAY (lines 890-1000 of the program) is used as follows:-

Delay = Time ship leaves berth - (Time of arrival + TIDE)
If delay <0, then minimum delay = 0, and idle time = - delay.

Since the system starts in an empty state, the time the previous ship left the berth = 0 (column 5, line 1 of Table 6.10), the ship enters berth number 2 (column 3, line 1).

TABLE 6.10 CALCULATIONS OF TIME SHIPS ENTERS AND LEAVES BERTH, DELAY, WAITING AND IDLE TIMES

(1) ARRIV.	(2) TIDE	(3) BERTH	(4) ENTER	(5) LEFT	(6) LEAVE	(7) DELAY	(8) SERV.	(9) WAIT	(10) IDLE
1. 456	6	2	462	0	679	0	217	6	462
2. 756	2	2	758	679	966	0	208	2	79
3. 997	0	2	997	966	1188	0	191	0	31
4. 1157	2	1	1159	0	1403	0	244	2	1159
5. 1333	1	2	1334	1118	1590	0	256	1	146
6. 1348	2	1	1403	1403	1600	53	196	55	0
7. 1421	1	2	1590	1590	1842	168	252	169	0
8. 1589	1	1	1600	1600	1838	10	238	11	0
9. 1731	4	1	1838	1838	2120	103	282	107	0
10. 1749	10	2	1842	1842	2023	181	181	93	0

DELAY = 0 - (456 + 6) = -462, meaning there is no delay, ie. DELAY = 0 (column 7, line 1) and

IDLE = - DELAY = - (-462) = 462 (column 10, line 1)

Time ship enters berth (ENTER) = Time of arrival + minimum delay

therefore, ENTER = 456 + 6 = 462 (column 4, line 1)

Waiting time (WAIT) = minimum delay + TDE

= 0 + 6 = 6 (column 9, line 1)

This berth becomes available when the ship leaves it (LEAVE)

= Time of arrival + minimum delay + service time

= 462 + 0 + 217 = 679 (column 6, line 1)

and applying the above procedure to the rest of the lines in Table 6.10 we get:-

<u>Line 2</u>
DELAY = 679 - 758 = - 79, ∴ DELAY = 0, IDLE = 79
ENTER = 756 + 2 = 758
WAIT = 0 + 2 = 2
LEAVE = 758 + 0 + 208 = 966

<u>Line 3</u>
DELAY = 966 - 977 = - 31, ∴ DELAY = 0, IDLE = 31
ENTER = 997 + 0 = 997
WAIT = 0 + 0 = 0
LEAVE = 997 + 0 + 191 = 1188

<u>Line 4</u>
DELAY = 0 - (1157 + 2) = - 1159, ∴ DELAY = 0, IDLE = 1159
ENTER = 1157 + 2 = 1159
WAIT = 0 + 2 = 2
LEAVE = 1159 + 0 + 244 = 1403

Notice here that berth Number 2 becomes available at 1188 hours and the arrival of the ship is at 1159 hours, since there are now two berths in this berth group, berth 1 is available now and the ship uses the first available berth.

<u>Line 5</u> The first available berth is Number 2 at 1188 hours (while Berth 1 becomes available at 1403 hours)

DELAY = 1188 - (1333 +1) = -146, ∴ DELAY = 0, IDLE = 146
ENTER = 1334 + 0 = 1334
WAIT = 0 + 1 = 1
LEAVE = 1334 + 0 + 256 = 1590

<u>Line 6</u> The first available berth is Number 1 at 1403 hours (while Berth Number 2 becomes available at 1590 hours)

DELAY = 1403 - (1348 + 2) = 53, ∴ IDLE = 0
ENTER = 1350 + 53 = 1403
WAIT = 2 + 53 = 55
LEAVE = 1350 + 54 + 196 = 1600

<u>Line 7</u> The first available berth is Number 2 at 1590 hours (while Berth 1 becomes available at 1600 hours)

DELAY = 1590 - 1422 = 168, ∴ IDLE = 0
ENTER = 1422 + 168 =1590
WAIT = 168 + 1 = 169
LEAVE = 1422 + 168 + 252 = 1842

<u>Line 8</u> DELAY = 1600 - 1590 = 10, ∴ IDLE = 0
ENTER = 1590 + 10 = 1600
WAIT = 10 + 1 = 11
LEAVE = 1590 + 10 + 238 = 1838

<u>Line 9</u> DELAY = 1838 - 1735 = 103 ∴ IDLE = 0
ENTER = 1735 + 103 =1838
WAIT = 103 + 4 = 107
LEAVE = 1735 + 103 + 282 = 2120

<u>Line 10</u> DELAY = 1842 - 1759 = 83, ∴ IDLE = 0
ENTER = 1759 + 83 = 1842
WAIT = 83 + 10 = 93
LEAVE = 1759 + 83 + 181 = 2023

All the results are shown in Table 6.10

Finally to calculate the queue size of ships as it gets bigger or smaller, an explanation of the subroutine PROCQSIZE (lines 1060-1220 of the program) is provided.

Consider an array Q with locations 0 to 10

0	1	2	3	4	5	6	7	8	9	10

delete from this end   add to this end

The values stored in the array are the times that the ships enter the berth, eg.

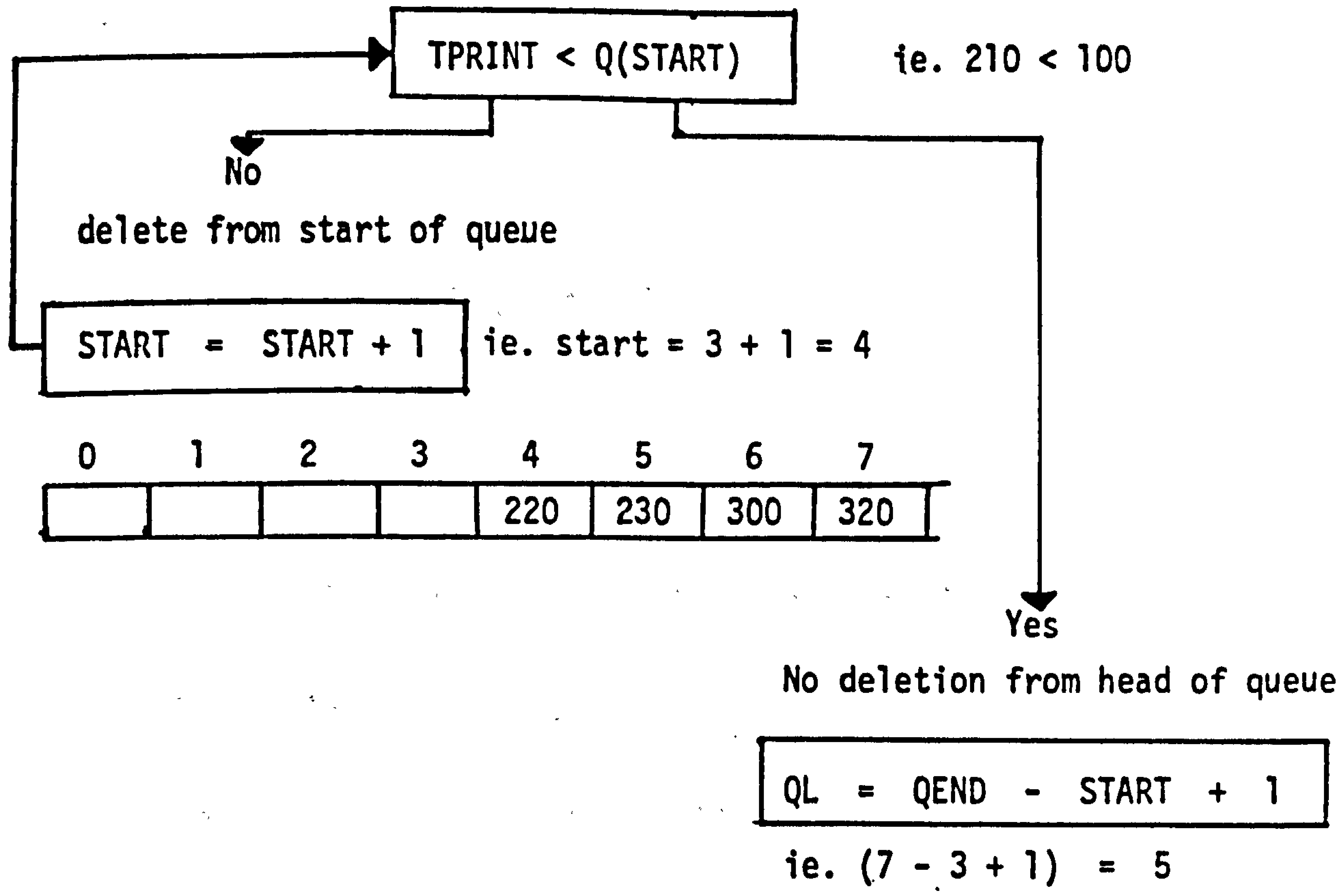
0	1	2	3	4	5	6	7	8	9	10
			100	220	230	300				

START represents the beginning of the queue ie. 3
FA represents the first available location ie. 7
QEND represents the end of the queue ie. 6

As each ship arrives, we know its arrival time (TPRINT) and the (calculated) time it enters its berth (ENTERB), for example, a ship arrives at 210 hours and enters berth at 320 hours, in line 1010 of the program, we set

Q (EA) = ENTERB, ie. Q(7) = 320

0	1	2	3	4	5	6	7	8	9	10
			100	220	230	300	320			



Applying the above procedure to our example, we know the time of arrival and the time the ship enters berth.

0	1	2	3	4	5	6	7	8	9	10
~~462~~	~~758~~	997								

referring to Table 6.10

<u>Line 1</u> we enter the time the ship enters berth in FA(0) = 462

456 < 462, Yes, QL = 0 - 0 + 1 = 1

<u>Line 2</u> we enter the time the ship enters berth in FA(1) = 758

756 < 462, No, START = START + 1 = 0 + 1

756 < 758, Yes, QL = QEND - START + 1 = 1 - 1 + 1 = 1

Line 3   997 < 758, No, START = START + 1 = 1 + 1 = 2

997 < 997, No, START = 0, FA = 0, QL = 0

0	1	2	3	4	5	6
~~1159~~	~~1334~~	~~1403~~	~~1590~~	~~1600~~	1838	1842

Line 4   1157 < 1159, Yes, QL = 0 - 0 + 1 = 1

Line 5   1333 < 1159, No, START = START + 1 = 0 + 1 = 1

1333 < 1334, Yes, QL = 1 - 1 + 1 = 1

Line 6   1348 < 1334, No, START = START + 1 = 1 + 1 = 2

1348 < 1403, Yes, QL = 2 - 2 + 1 = 1

Line 7   1421 < 1403, No, START = START + 1 = 2 + 1 = 3

1421 < 1590, Yes, QL = 3 - 3 + 1 = 1

Line 8   1589 < 1590, Yes, QL = 4 - 3 + 1 = 2

Line 9   1731 < 1590, No, START = START + 1 = 3 + 1 = 4

1731 < 1600, No, START = START + 1 = 4 + 1 = 5

1731 < 1838, Yes, QL = 5 - 5 + 1 = 1

Line 10   1749 < 1838, Yes, QL = 6 - 5 + 1 = 2

TITLES USED IN SIMULATION PROGRAMME

1.	TYPE	Type of ship arriving
2.	DAY	Time of arrival of ship in days
3.	HR	Time or arrival of ship in hours
4.	TIDE	Delay caused due to tides and shifts
5.	BTH	Type of berth - usually same as 1 above except occasionally when Grain ships use General Cargo berths.
6.	BTH	Number of berth used in the berth group
7.	Q	Queue length
8.	ARRIV	Ship arrival time in hours
9.	ENTER	Time ship enters berth
10.	LEFT	Time previous ship left berth
11.	LEAVE	Time this ship will leave berth
12.	DELAY	Delay caused by waiting for free berth
13.	SERV	Time taken to service ship
14.	WAIT	Total waiting time for ship
15.	IDLE	Berth idle time
16.	AV.WT	Average waiting time
17.	NO.ARRIV.	Number of arrivals over simulation period

18.	TOT.IDLETIME	Total idle time for the group of berths
19.	% IDLE TIME	Percentage idle time for the group of berths
20.	AV.SERVICE	Average time taken to service ship
21.	MAX Q	Maximum queue length

VARIABLES USED IN SIMULATION PROGRAMME

NOARRIVS	Number of ships arriving during simulation period including run-in-time
FDAYS	First arrivals (for run-in-time)
T	Type of ship eg. 1. General cargo 2. Grain 3. Oil 4. Urea Basra Port 1979
NT	Number of types
NN	Number of arrivals
NOSHIPS	Number of ships arriving per year for each class (this is read from the first column in DATA)
TCONST	Mean interarrival time between ships (λ)
NOBERTHS	Number of berths for each class (this is read from the second column in DATA)
TSERV	Mean service time for each class (this is read from the third column in DATA)
STD	Standard deviation for each class (this is read from the fourth column in DATA)
MAXQL	Maximum queue length
QUEUE	Either TRUE or FALSE depending on whether queue is normal or turned back on itself

START	Start of queue
FA	First available location in array Q
STIME	Time of arrival of ship
TINTERV	Time interval between arrivals
GRAIN	Either 1 or 0 depending whether it is a grain ship or not
XSTIME	Total excess time for ship
IDLET	Berth idle time
TYPE	Type of berth
FIRST	This is first available berth
TPRINT	Time or arrival + waiting due to tide
MINDELAY	Minimum delay
BERTH(N,TYPL)	Time ship will leave berth N
ENTERB	Time ship enters berth
WAITIME	Waiting time of ship
SUMIT	Sum of idle time
SUM	Sum of waiting time
SUMSERV	Sum of service time
NO	Number of ships arriving during simulation

TITOT	TOTAL SIMULATION TIME
FOUND	Flag to note whether an empty berth has been found or not
CHTYPE	Either 1 or 0 depending on whether or not a general cargo berth is being used by a grain ship.
DELAY	Time to wait before a berth becomes available
QEND	End of queue
ARRAYSZE	Size of array
QL	Queue length
Q	Array which stores the times at which ships enter the berth
NEWDAYS	Day that ship arrives
XST	Excess time caused by either tides or shift (night)
TIDE 1	Times when the tides are in and out
TIDE 2	The ships cannot enter or leave the berth
TIDE 3	between Tide 1 and Tide 2, and Tide 3
TIDE 4	and Tide 4
T1	Times when ports are not operational due to shifts
T2	ships cannot enter the berths between T1 and T2

```
>L.
   10 REM READ DATA: array size, no. of arrivals simulated, no. of arrivals ignored, no. of different types.
   20 READ ARRAYSIZE,NOARRIVS,FDAYS,NT
   30 DATA 50,426,213,4
   40 REM   DATA: For each type: No. ships, no. berths, mean service time, standard deviation of service time.
   50 DATA 44,1,159,40
   60 DATA 69,2,236,38
   70 DATA 75,2,159,35
   80 DATA 25,1,159,26
   90 R=RND(-1)
  100 DAYSYR=365 : HRSDAY=24 :TIDE1=0:NEWDAYS=-1:NN=1
  110 DIM SUMSERV(4),NUMB(4),STD(4),C(100,4),CI(500,4),Q(ARRAYSIZE,4)
  120 DIM START(4),FA(4),QUEUE(4),MAXQL(4),CQ(50,4)
  130 DIM AVLOAD(4),AVUNLOAD(4),STIME(4),TCONST(4),NOBERTHS(4),BERTH(15,4)
  140 DIM TSERV(4),SUM(4),NO(4),SUMIT(4)
  150 @%=&01000004
  160 PRINT''''"Type 1-Fertilisers"'"Type 2-Sulphur":PRINT"Type 3-Urea"'"Type 4-Phosphates"''''''
  170 PRINT" TYPE DAY HR TIDE BTH BTH  Q  ";
  180 @%=&01000007
  190 PRINT  " ARRIV ENTER  LEFT LEAVE  DELAY   SERV  WAIT IDLE"
  200 FOR T=1 TO NT:READ NOSHIPS:TCONST(T)=DAYSYR*HRSDAY/NOSHIPS
  210READ NOBERTHS(T),TSERV(T),STD(T):NEXTT
  220    REM***CALC.TIMEINTERVAL CONSTANT FOR EACH SHIP
  230 FOR T=1 TO NT:TCONST=TCONST(T):PROCINTERV
  240    REM***CALC TIME OF FIRST SHIP OF EACH TYPE.
  250 MAXQL(T)=0:QUEUE(T)=TRUE:START(T)=0: FA(T)=0
  260 STIME(T)=TINTERV:NEXT
  270   REM***FIND EARLIEST SHIP.
  280 GOTO290:FOR T=1 TO 3:STIME(T)=10^6:NO(T)=1:NUMB(T)=1 :NEXTT
  290 XSTIME=0:IDLET=0: STIME=10^6:FOR T=1 TO NT
  300IF STIME(T)<STIME THENSTIME=INT(STIME(T)):TYPE=T
  310 NEXT T:TPRINT=STIME
  320 HOURS=STIME MOD 24: DAYS=STIME DIV 24 :HRS=HOURS
  330 PROCDELAY(STIME)
  340 STIME=STIME+XSTIME
  350   REM*** CALC TIME TO LOAD & UNLOAD.
  360 PROCNORMAL
  370 NOBERTH=NOBERTHS(TYPE):MINDELAY=100000
  380 @%=&00000004
  400 PRINT  TYPE,DAYS,HRS,XSTIME;
  410 PROCMINDELAY
  440 ENTERB=STIME+MINDELAY:PROCQSIZE :PRINT TYPE,FIRST,QL;
  450 @%=&00020006:PRINT TPRINT,ENTERB,BERTH(FIRST,TYPE);
  460 WAITIME=MINDELAY+XSTIME
  470
  480 BERTH(FIRST,TYPE)=STIME+MINDELAY+TSERVICE :HOURS=BERTH(FIRST,TYPE) MOD 24: LTIME=BERTH(FIRST,TYPE)
  490 HR=HOURS
  500 XSTIME=0: PROCDELAY(LTIME)
  510 TSERVICE=TSERVICE+XSTIME: BERTH(FIRST,TYPE)=BERTH(FIRST,TYPE)+XSTIME
```

```
520 IF NN>FDAYS THEN SUMIT(TYPE)=SUMIT(TYPE)+IDLET:CQ(QL,TYPE)= CQ(QL,TYPE)+1
530 PRINT BERTH(FIRST,TYPE);"  ";
540 @%=&00020005:PRINT MINDELAY,TSERVICE,WAITIME,IDLET
560 IF NN<=FDAYS GOTO 600
570 SUM(TYPE)=SUM(TYPE)+WAITIME :NO(TYPE)=NO(TYPE)+1 : SUMSERV(TYPE)=SUMSERV(TYPE)+TSERVICE:WT=INT(WAITIME/12):IF WT>50 THEN WT=50
580 IT=INT(IDLET/12):IF IT>100 THEN IT=100
590 C(WT,TYPE)=C(WT,TYPE)+1:CI(IT,TYPE)=CI(IT,TYPE)+1
600 TCONST=TCONST(TYPE)
610 IF NN=FDAYS THEN FDAYTIME=STIME
620 PROCINTERV
630 STIME(TYPE)=STIME(TYPE)+TINTERV
640 IF NN=NOARRIVS-10 THEN VDU2
650 NN=NN+1:IF NN<=NOARRIVS GOTO290
660PRINT' "FIRST ";FDAYS;" ARRIVALS IGNORED."
670 @%=&0002020B :TIMTOT=TPRINT-FDAYTIME
680 PRINT "        TYPE   NO.ARRIV.   AV.WT.    TOT.IDLETIME %IDLE TIME AV SERVICE  MAXQ"
690 FOR T=1 TO NT:PRINTT,NO(T),SUM(T)/NO(T),SUMIT(T),SUMIT(T)/TIMTOT*100,SUMSERV(T)/NO(T),MAXQL(T)
700 NEXT T
710 @%=&00000004
720 FOR T=1 TO NT :PRINT '"TYPE=";T;" QUEUE LENGTHS"
730 FOR IQ=0 TO MAXQL(T) :PRINT IQ,CQ(IQ,T)
740 NEXT IQ: NEXT T
750 FOR T=1 TO NT :PRINT''"TYPE=";T ;" WAITING TIMES"
760 ZZ=0: FOR IW=0 TO 100
770 IF C(IW,T)<>0 PRINT TAB(ZZ);IW*12;"-";IW*12+11.99,C(IW,T);"      ";:K=K+1:ZZ=25*(K MOD 3): IF ZZ=0 THEN PRINT
780 NEXT IW
790 NEXT T
800 FOR T=1 TO NT :PRINT''"TYPE=";T; " IDLE TIMES"
810 K=0 :ZZ=0:FOR IW=0 TO 200
820 IF CI(IW,T)<>0 PRINT TAB(ZZ);IW*12;"-";IW*12+11.99,CI(IW,T);"      ";:K=K+1:ZZ=25*(K MOD 3):IF ZZ=0 THENPRINT
830 NEXT:NEXT  :PRINT
840 @%=10:VDU3:STOP
850 DEF PROCINTERV
860 R=RND(1)
870 TINTERV=-TCONST*LN(1-R)
880 ENDPROC
890 DEF PROCMINDELAY
900 FOUND=0 :CHTYPE=0
910   REM***CHECK ALL BERTHS OF THIS TYPE.
920 FOR N=1 TO NOBERTH
940 DELAY=BERTH(N,TYPE)-STIME
950 IF DELAY<0 THEN MINDELAY=0 :FIRST=N :IDLET=-DELAY:GOTO970
960 IF DELAY<MINDELAY THEN MINDELAY=DELAY:FIRST=N
970 NEXT N
1000 ENDPROC
1010 DEF PROCNORMAL
1020 SUMN=0:FOR I=1 TO 12:R=RND(1)
1030 SUMN=SUMN+R:NEXT I
1040 TSERVICE=STD(TYPE)*(SUMN-6.0)+TSERV(TYPE)
1050 ENDPROC
1060 DEF PROCQSIZE
```

```
1070 START=START(TYPE):FA=FA(TYPE):QUEUE=QUEUE(TYPE)
1080 Q(FA,TYPE)=ENTERB
1090 QEND=FA
1100 IF TPRINT<Q(START,TYPE) GOTO 1160
1110 IF QUEUE AND START<QEND THEN START=START+1 :GOTO 1100
1120 IF QUEUE AND START>=QEND THEN START=0 :  FA=0:QL=0:GOTO 1200
1130 START=START+1
1140 IF START>ARRAYSIZE THEN START=0:QUEUE=TRUE
1150 GOTO 1100
1160 IF QUEUE THEN QL=QEND-START+1 ELSE QL=ARRAYSZE-START+QEND+2
1170 FA=FA+1
1180 IF FA>ARRAYSZE THEN FA=0:QUEUE=FALSE
1190 IF QUEUE=FALSE AND FA>START THEN PRINT"Q TOO LONG";" START="START;" FA=";FA ;" QL=";QL
1200 START(TYPE)=START:FA(TYPE)=FA:QUEUE(TYPE)=QUEUE
1210 IF QL>MAXQL(TYPE) THEN MAXQL(TYPE)=QL
1220 ENDPROC
1230 DEF  PROCDELAY(LSTIME)
1240 PROCXSTIME(0,6,HOURS):PROCXSTIME(18,30,HOURS)
1250 D=DAYS-NEWDAYS :IF D=0 GOTO 1300
1260 TIDE1=(TIDE1+D) MOD 24
1270 TIDE2=(TIDE1+6) MOD 24
1280 TIDE3=(TIDE1+12) MOD 24
1290 TIDE4=(TIDE1+18) MOD 24
1300 NEWDAYS=DAYS
1310 IF TIDE2<TIDE1 THEN PROCXSTIME(0,TIDE2,HOURS): PROCXSTIME(TIDE1,TIDE2+24,HOURS)ELSE PROCXSTIME(TIDE1,TIDE2,HOURS)
1320 IF TIDE4<TIDE3 THEN PROCXSTIME(0,TIDE4,HOURS):PROCXSTIME(TIDE3,TIDE4+24,HOURS) ELSE PROCXSTIME(TIDE3,TIDE4,HOURS)
1330 IF XST<>0 GOTO 1240
1340 ENDPROC
1350  DEF PROCXSTIME(T1,T2,H)
1360 XST=0
1370 IF H>=T1 AND H<T2 THEN XST=T2-H :XSTIME=XSTIME+XST :HOURS=(LSTIME+XSTIME) MOD 24
1380 ENDPROC
```

```
>RUN
```

Type 1-Fertilisers
Type 2-Sulphur
Type 3-Urea
Type 4-Phosphates

TYPE	DAY	HR	TIDE	BTH	BTH	Q	ARRIV	ENTER	LEFT	LEAVE	DELAY	SERV	WAIT	IDLE	
3	0	0	7	3	2	1	0.	7.	0.	175.	0.	168.	7.	7.	
3	0	11	0	3	1	0	11.	11.	0.	152.	0.	141.	0.	11.	
3	1	22	10	3	1	1	46.	152.	152.	298.	96.	147.	106.	0.	
4	10	3	3	4	1	1	243.	246.	0.	440.	0.	194.	3.	246.	
3	11	14	4	3	2	1	278.	282.	175.	489.	0.	207.	4.	107.	
3	14	22	11	3	1	1	358.	369.	298.	468.	0.	99.	11.	71.	
2	19	0	6	2	2	1	456.	462.	0.	679.	0.	217.	6.	462.	1
3	20	3	3	3	1	1	483.	486.	468.	679.	0.	193.	3.	18.	
4	23	23	7	4	1	1	575.	582.	440.	707.	0.	125.	7.	142.	
3	25	13	0	3	2	0	613.	613.	489.	753.	0.	140.	0.	124.	
3	25	20	12	3	1	1	620.	679.	679.	802.	47.	123.	59.	0.	
4	30	17	0	4	1	0	737.	737.	707.	853.	0.	116.	0.	30.	
2	31	12	2	2	2	1	756.	758.	679.	966.	0.	208.	2.	79.	2
3	32	13	2	3	2	1	781.	783.	753.	919.	0.	136.	2.	30.	
3	35	3	3	3	1	1	843.	846.	802.	990.	0.	144.	3.	44.	
2	41	13	0	2	2	0	997.	997.	966.	1188.	0.	191.	0.	31.	3
1	46	5	1	1	1	1	1109.	1110.	0.	1255.	0.	145.	1.	1110.	
2	48	5	2	2	1	1	1157.	1159.	0.	1403.	0.	244.	2.	1159.	4
1	51	22	12	1	1	1	1246.	1258.	1255.	1426.	0.	168.	12.	3.	
1	51	22	12	1	1	2	1246.	1426.	1426.	1619.	168.	193.	180.	0.	
3	52	11	0	3	2	0	1259.	1259.	919.	1451.	0.	192.	0.	340.	
2	55	13	1	2	2	1	1333.	1334.	1188.	1590.	0.	256.	1.	146.	5
3	56	2	4	3	1	1	1346.	1350.	990.	1496.	0.	146.	4.	360.	
2	56	4	2	2	1	1	1348.	1403.	1403.	1600.	53.	196.	55.	0.	6
2	59	5	1	2	2	1	1421.	1590.	1590.	1842.	168.	252.	169.	0.	7
4	59	15	3	4	1	1	1431.	1434.	853.	1626.	0.	192.	3.	581.	
3	61	6	2	3	2	1	1470.	1472.	1451.	1641.	0.	169.	2.	21.	
3	63	14	0	3	1	0	1526.	1526.	1496.	1679.	0.	153.	0.	30.	
3	63	15	0	3	2	1	1527.	1641.	1641.	1811.	114.	170.	114.	0.	
2	66	5	1	2	1	2	1589.	1600.	1600.	1838.	10.	238.	11.	0.	8
3	66	11	2	3	1	2	1595.	1679.	1679.	1839.	82.	160.	84.	0.	
2	72	3	4	2	1	1	1731.	1838.	1838.	2120.	103.	282.	107.	0.	9
2	72	21	10	2	2	2	1749.	1842.	1842.	2023.	83.	181.	93.	0.	10
4	73	3	5	4	1	1	1755.	1760.	1626.	1976.	0.	216.	5.	134.	
1	75	18	16	1	1	1	1818.	1834.	1619.	2003.	0.	169.	16.	215.	

2	77	1	11	2	2	1	1849.	2023.	2023.	2250.	163.	227.	174.	0.
2	77	18	18	2	1	2	1866.	2120.	2120.	2365.	236.	245.	254.	0.
3	79	15	0	3	2	0	1911.	1911.	1811.	2150.	0.	239.	0.	100.
4	80	5	1	4	1	1	1925.	1976.	1976.	2080.	50.	103.	51.	0.
2	88	0	11	2	2	2	2112.	2250.	2250.	2508.	127.	258.	138.	0.
2	92	10	5	2	1	2	2218.	2365.	2365.	2607.	142.	243.	147.	0.
2	94	10	0	2	2	2	2266.	2508.	2508.	2742.	242.	235.	242.	0.
3	96	14	17	3	2	1	2318.	2335.	2150.	2504.	0.	169.	17.	185.
3	97	8	0	3	1	0	2336.	2336.	1839.	2504.	0.	168.	0.	497.
3	97	18	14	3	2	1	2346.	2504.	2504.	2696.	144.	193.	158.	0.
3	100	12	0	3	1	2	2412.	2504.	2504.	2603.	92.	99.	92.	0.
2	101	7	5	2	1	2	2431.	2607.	2607.	2869.	171.	262.	176.	0.
2	104	7	0	2	2	3	2503.	2742.	2742.	3040.	239.	297.	239.	0.
2	104	18	12	2	1	3	2514.	2869.	2869.	3078.	343.	209.	355.	0.
2	105	8	0	2	2	4	2528.	3040.	3040.	3353.	512.	313.	512.	0.
3	108	6	1	3	1	1	2598.	2603.	2603.	2767.	4.	164.	5.	0.
4	110	7	2	4	1	1	2647.	2649.	2080.	2853.	0.	204.	2.	569.
2	110	22	11	2	1	4	2662.	3078.	3078.	3297.	405.	219.	416.	0.
2	114	9	4	2	1	4	2745.	3297.	3297.	3582.	548.	285.	552.	0.
3	114	19	11	3	2	1	2755.	2766.	2696.	2958.	0.	192.	11.	70.
1	116	16	0	1	1	0	2800.	2800.	2003.	2983.	0.	183.	0.	797.
2	118	16	1	2	2	5	2848.	3353.	3353.	3562.	504.	209.	505.	0.
3	119	12	18	3	1	1	2868.	2886.	2767.	3054.	0.	168.	18.	119.
3	120	17	14	3	2	1	2897.	2958.	2958.	3106.	47.	147.	61.	0.
3	120	18	13	3	1	2	2898.	3054.	3054.	3229.	143.	175.	156.	0.
3	122	2	7	3	2	3	2930.	3106.	3106.	3279.	169.	173.	176.	0.
4	123	0	10	4	1	1	2952.	2962.	2853.	3106.	0.	144.	10.	109.
1	127	16	0	1	1	0	3064.	3064.	2983.	3223.	0.	159.	0.	81.
1	132	0	7	1	1	1	3168.	3223.	3223.	3319.	48.	97.	55.	0.
2	136	2	9	2	2	3	3266.	3562.	3562.	3876.	287.	314.	296.	0.
1	136	18	17	1	1	1	3282.	3319.	3319.	3444.	20.	125.	37.	0.
3	143	6	0	3	2	0	3438.	3438.	3279.	3607.	0.	169.	0.	159.
1	144	10	0	1	1	0	3466.	3466.	3444.	3632.	0.	166.	0.	22.
3	146	15	18	3	1	1	3519.	3537.	3229.	3657.	0.	120.	18.	308.
3	148	13	0	3	2	1	3565.	3607.	3607.	3758.	42.	151.	42.	0.
2	153	5	1	2	1	1	3677.	3678.	3582.	3895.	0.	217.	1.	96.
2	153	9	0	2	2	1	3681.	3876.	3876.	4086.	195.	210.	195.	0.
2	154	9	0	2	1	2	3705.	3895.	3895.	4110.	190.	215.	190.	0.
4	154	23	7	4	1	1	3719.	3726.	3106.	3870.	0.	144.	7.	620.
2	156	3	4	2	2	3	3747.	4086.	4086.	4303.	335.	217.	339.	0.
3	156	11	0	3	1	0	3755.	3755.	3657.	3955.	0.	200.	0.	98.
4	156	13	6	4	1	1	3757.	3870.	3870.	4020.	107.	149.	113.	0.
2	157	6	2	2	1	4	3774.	4110.	4110.	4332.	334.	222.	336.	0.
3	158	1	8	3	2	1	3793.	3801.	3758.	3994.	0.	193.	8.	43.
2	158	7	2	2	2	5	3799.	4303.	4303.	4569.	502.	266.	504.	0.
2	160	1	10	2	1	6	3841.	4332.	4332.	4647.	481.	315.	491.	0.
1	160	6	5	1	1	1	3846.	3851.	3632.	4043.	0.	192.	5.	219.
3	162	13	0	3	1	1	3901.	3955.	3955.	4093.	54.	138.	54.	0.
2	163	0	6	2	2	5	3912.	4569.	4569.	4791.	651.	221.	657.	0.

2	164	10	5	2	1	6	3946.	4647.	4647.	4879.	696.	232.	701.	0.
1	167	10	0	1	1	1	4018.	4043.	4043.	4230.	25.	187.	25.	0.
3	168	22	9	3	2	1	4054.	4063.	3994.	4258.	0.	195.	9.	69.
1	170	1	8	1	1	1	4081.	4230.	4230.	4377.	141.	147.	149.	0.
1	172	19	16	1	1	2	4147.	4377.	4377.	4595.	214.	218.	230.	0.
3	175	8	6	3	1	1	4208.	4214.	4093.	4382.	0.	168.	6.	121.
3	176	7	0	3	2	1	4231.	4258.	4258.	4359.	27.	101.	27.	0.
3	178	14	3	3	2	1	4286.	4359.	4359.	4475.	70.	116.	73.	0.
3	180	4	3	3	1	2	4324.	4382.	4382.	4532.	55.	150.	58.	0.
1	180	20	11	1	1	2	4340.	4595.	4595.	4699.	244.	104.	255.	0.
4	182	10	0	4	1	0	4378.	4378.	4020.	4570.	0.	192.	0.	358.
2	182	21	12	2	2	3	4389.	4791.	4791.	5002.	390.	211.	402.	0.
2	183	4	6	2	1	4	4396.	4879.	4879.	5101.	477.	222.	483.	0.
3	186	12	1	3	2	1	4476.	4477.	4475.	4646.	0.	169.	1.	2.
3	188	12	3	3	1	1	4524.	4532.	4532.	4688.	5.	156.	8.	0.
3	190	7	0	3	2	1	4567.	4646.	4646.	4806.	79.	160.	79.	0.
1	190	19	11	1	1	2	4579.	4699.	4699.	4817.	109.	118.	120.	0.
4	192	8	0	4	1	0	4616.	4616.	4570.	4738.	0.	122.	0.	46.
1	194	5	4	1	1	2	4661.	4817.	4817.	5026.	152.	208.	156.	0.
2	196	4	7	2	2	3	4708.	5002.	5002.	5224.	287.	222.	294.	0.
2	196	11	0	2	1	4	4715.	5101.	5101.	5339.	386.	239.	386.	0.
2	197	2	10	2	2	5	4730.	5224.	5224.	5484.	484.	260.	494.	0.
3	198	23	7	3	1	1	4775.	4782.	4688.	4927.	0.	145.	7.	94.
1	199	16	0	1	1	2	4792.	5026.	5026.	5294.	234.	269.	234.	0.
3	200	17	0	3	2	0	4817.	4817.	4806.	5023.	0.	206.	0.	11.
3	205	14	6	3	1	1	4934.	4940.	4927.	5120.	0.	180.	6.	13.
3	205	20	12	3	2	1	4940.	5023.	5023.	5168.	71.	145.	83.	0.
3	206	18	15	3	1	2	4962.	5120.	5120.	5265.	143.	145.	158.	0.
2	208	4	7	2	1	4	4996.	5339.	5339.	5560.	336.	221.	343.	0.
3	210	10	3	3	2	2	5050.	5168.	5168.	5335.	115.	167.	118.	0.
4	213	2	4	4	1	1	5114.	5118.	4738.	5262.	0.	144.	4.	380.
1	214	19	11	1	1	1	5155.	5294.	5294.	5456.	128.	161.	139.	0.
1	216	2	5	1	1	2	5186.	5456.	5456.	5647.	265.	192.	270.	0.
1	216	14	17	1	1	3	5198.	5647.	5647.	5840.	432.	192.	449.	0.
2	216	15	16	2	2	3	5199.	5484.	5484.	5767.	269.	283.	285.	0.
4	218	21	12	4	1	1	5253.	5265.	5262.	5410.	0.	145.	12.	3.
2	219	8	2	2	1	3	5264.	5560.	5560.	5819.	294.	258.	296.	0.
2	221	7	5	2	2	4	5311.	5767.	5767.	6036.	451.	269.	456.	0.
4	223	1	5	4	1	1	5353.	5410.	5410.	5599.	52.	189.	57.	0.
4	225	3	3	4	1	2	5403.	5599.	5599.	5791.	193.	192.	196.	0.
2	225	19	11	2	1	4	5419.	5819.	5819.	6078.	389.	260.	400.	0.
1	227	11	0	1	1	2	5459.	5840.	5840.	6030.	381.	191.	381.	0.
2	229	22	10	2	2	4	5518.	6036.	6036.	6200.	508.	164.	518.	0.
3	231	1	9	3	2	1	5545.	5554.	5335.	5687.	0.	133.	9.	219.
3	231	5	5	3	1	2	5549.	5554.	5265.	5703.	0.	149.	5.	289.
3	231	6	4	3	2	3	5550.	5687.	5687.	5854.	133.	168.	137.	0.
3	234	8	5	3	1	2	5624.	5703.	5703.	5862.	74.	160.	79.	0.
3	235	4	2	3	2	3	5644.	5854.	5854.	5991.	208.	136.	210.	0.
2	237	11	5	2	1	4	5699.	6078.	6078.	6319.	374.	240.	379.	0.
2	243	11	0	2	2	3	5843.	6200.	6200.	6446.	357.	246.	357.	0.

4	244	1	10	4	1	1	5857.	5867.	5791.	6060.	0.	193.	10.	76.
1	244	12	0	1	1	1	5868.	6030.	6030.	6180.	162.	149.	162.	0.
3	244	16	0	3	1	0	5872.	5872.	5862.	6035.	0.	163.	0.	10.
3	244	18	17	3	2	1	5874.	5991.	5991.	6203.	100.	212.	117.	0.
1	246	13	0	1	1	2	5917.	6180.	6180.	6318.	263.	139.	263.	0.
3	253	10	0	3	1	0	6082.	6082.	6035.	6248.	0.	166.	0.	47.
3	253	22	10	3	2	1	6094.	6203.	6203.	6380.	99.	177.	109.	0.
3	256	10	1	3	1	2	6154.	6248.	6248.	6419.	93.	171.	94.	0.
4	258	4	2	4	1	1	6196.	6198.	6060.	6342.	0.	144.	2.	138.
2	260	5	1	2	1	1	6245.	6319.	6319.	6519.	73.	201.	74.	0.
2	260	19	11	2	2	2	6259.	6446.	6446.	6616.	176.	169.	187.	0.
2	261	14	2	2	1	3	6278.	6519.	6519.	6784.	239.	265.	241.	0.
2	261	21	9	2	2	4	6285.	6616.	6616.	6775.	322.	159.	331.	0.
3	271	10	4	3	2	1	6514.	6518.	6380.	6678.	0.	160.	4.	138.
2	272	8	0	2	2	2	6536.	6775.	6775.	7023.	239.	249.	239.	0.
3	274	7	0	3	1	0	6583.	6583.	6419.	6654.	0.	71.	0.	164.
2	275	7	0	2	1	3	6607.	6784.	6784.	6990.	177.	206.	177.	0.
3	275	22	8	3	1	1	6622.	6654.	6654.	6753.	24.	98.	32.	0.
2	276	2	5	2	1	3	6626.	6990.	6990.	7232.	359.	241.	364.	0.
1	276	10	0	1	1	0	6634.	6634.	6318.	6776.	0.	142.	0.	316.
2	277	5	3	2	2	4	6653.	7023.	7023.	7245.	367.	221.	370.	0.
2	281	21	15	2	1	5	6765.	7232.	7232.	7476.	452.	244.	467.	0.
2	282	0	6	2	2	6	6768.	7245.	7245.	7446.	471.	201.	477.	0.
2	285	4	2	2	2	5	6844.	7446.	7446.	7687.	600.	240.	602.	0.
1	285	14	2	1	1	1	6854.	6856.	6776.	7073.	0.	217.	2.	80.
1	285	23	7	1	1	1	6863.	7073.	7073.	7279.	203.	206.	210.	0.
2	290	18	15	2	1	6	6978.	7476.	7476.	7785.	483.	309.	498.	0.
1	291	15	0	1	1	2	6999.	7279.	7279.	7475.	280.	196.	280.	0.
2	292	6	5	2	2	6	7014.	7687.	7687.	7931.	668.	245.	673.	0.
4	292	8	3	4	1	1	7016.	7019.	6342.	7235.	0.	216.	3.	677.
2	292	9	2	2	1	7	7017.	7785.	7785.	8051.	766.	266.	768.	0.
2	292	11	0	2	2	8	7019.	7931.	7931.	8126.	912.	195.	912.	0.
3	292	18	17	3	2	1	7026.	7043.	6678.	7260.	0.	217.	17.	365.
2	293	17	0	2	1	8	7049.	8051.	8051.	8268.	1002.	217.	1002.	0.
2	294	7	6	2	2	9	7063.	8126.	8126.	8365.	1057.	240.	1063.	0.
1	295	15	0	1	1	2	7095.	7475.	7475.	7575.	380.	100.	380.	0.
3	296	8	0	3	1	0	7112.	7112.	6753.	7302.	0.	190.	0.	359.
4	297	2	4	4	1	1	7130.	7235.	7235.	7376.	101.	141.	105.	0.
2	297	4	2	2	1	10	7132.	8268.	8268.	8503.	1134.	234.	1136.	0.
1	298	8	0	1	1	3	7160.	7575.	7575.	7786.	415.	211.	415.	0.
1	298	19	11	1	1	4	7171.	7786.	7786.	8009.	604.	223.	615.	0.
3	300	4	3	3	2	1	7204.	7260.	7260.	7435.	53.	175.	56.	0.
3	300	13	6	3	1	2	7213.	7302.	7302.	7423.	83.	121.	89.	0.
2	302	7	2	2	2	9	7255.	8365.	8365.	8553.	1108.	188.	1110.	0.
2	304	3	8	2	1	10	7299.	8503.	8503.	8760.	1196.	257.	1204.	0.
4	304	16	0	4	1	1	7312.	7376.	7376.	7572.	64.	196.	64.	0.
3	304	22	13	3	1	1	7318.	7423.	7423.	7524.	92.	101.	105.	0.
2	304	23	12	2	2	11	7319.	8553.	8553.	8772.	1222.	219.	1234.	0.
2	306	8	5	2	1	12	7352.	8760.	8760.	9006.	1403.	246.	1408.	0.

1	306	12	1	1	1	4	7356.	8009.	8009.	8202.	652.	192.	653.	0.
2	310	18	12	2	2	12	7458.	8772.	8772.	9031.	1302.	259.	1314.	0.
1	311	9	0	1	1	5	7473.	8202.	8202.	8358.	729.	157.	729.	0.
1	312	18	13	1	1	5	7506.	8358.	8358.	8552.	839.	193.	852.	0.
1	315	9	1	1	1	6	7569.	8552.	8552.	8650.	982.	99.	983.	0.
2	317	4	8	2	1	12	7612.	9006.	9006.	9205.	1386.	199.	1394.	0.
2	317	6	6	2	2	13	7614.	9031.	9031.	9229.	1411.	198.	1417.	0.
1	317	14	0	1	1	6	7622.	8650.	8650.	8825.	1028.	175.	1028.	0.
3	317	20	16	3	2	1	7628.	7644.	7435.	7813.	0.	169.	16.	209.
4	318	15	0	4	1	0	7647.	7647.	7572.	7830.	0.	183.	0.	75.
3	319	9	5	3	1	1	7665.	7670.	7524.	7832.	0.	162.	5.	146.
2	321	16	0	2	1	13	7720.	9205.	9205.	9487.	1485.	282.	1485.	0.
2	326	0	9	2	2	13	7824.	9229.	9229.	9465.	1396.	236.	1405.	0.
1	327	19	15	1	1	6	7867.	8825.	8825.	8987.	943.	162.	958.	0.
3	328	7	4	3	2	1	7879.	7883.	7813.	8031.	0.	148.	4.	70.
3	330	6	0	3	1	0	7926.	7926.	7832.	8079.	0.	153.	0.	94.
4	330	10	3	4	1	1	7930.	7933.	7830.	8094.	0.	161.	3.	103.
1	330	22	8	1	1	7	7942.	8987.	8987.	9127.	1037.	140.	1045.	0.
2	333	6	0	2	2	13	7998.	9465.	9465.	9774.	1467.	309.	1467.	0.
3	333	20	10	3	2	1	8012.	8031.	8031.	8190.	9.	160.	19.	0.
4	334	22	8	4	1	1	8038.	8094.	8094.	8239.	48.	144.	56.	0.
1	336	6	1	1	1	7	8070.	9127.	9127.	9295.	1056.	169.	1057.	0.
3	338	12	0	3	1	0	8124.	8124.	8079.	8265.	0.	141.	0.	45.
3	338	17	16	3	2	1	8129.	8190.	8190.	8410.	45.	219.	61.	0.
4	338	19	14	4	1	1	8131.	8239.	8239.	8434.	94.	195.	108.	0.
3	339	17	17	3	1	2	8153.	8265.	8265.	8435.	95.	169.	112.	0.
2	339	22	12	2	1	12	8158.	9487.	9487.	9731.	1317.	244.	1329.	0.
3	339	23	11	3	2	3	8159.	8410.	8410.	8651.	240.	241.	251.	0.
2	340	3	8	2	1	13	8163.	9731.	9731.	9947.	1560.	217.	1568.	0.
3	343	11	3	3	1	3	8243.	8435.	8435.	8574.	189.	139.	192.	0.
3	345	1	5	3	1	3	8281.	8574.	8574.	8752.	288.	178.	293.	0.
3	349	0	8	3	2	4	8376.	8651.	8651.	8852.	267.	202.	275.	0.
1	349	16	4	1	1	6	8392.	9295.	9295.	9465.	899.	169.	903.	0.
2	349	21	11	2	2	12	8397.	9774.	9774.	9969.	1366.	194.	1377.	0.
1	353	13	0	1	1	7	8485.	9465.	9465.	9636.	980.	172.	980.	0.
4	354	16	0	4	1	0	8512.	8512.	8434.	8695.	0.	183.	0.	78.
3	355	1	5	3	1	3	8521.	8752.	8752.	8969.	226.	217.	231.	0.
1	356	0	6	1	1	8	8544.	9636.	9636.	9822.	1086.	186.	1092.	0.
2	357	15	1	2	1	11	8583.	9947.	9947.	10193.	1363.	245.	1364.	0.
2	358	6	0	2	2	12	8598.	9969.	9969.	10182.	1371.	213.	1371.	0.
1	358	7	0	1	1	8	8599.	9822.	9822.	9991.	1223.	169.	1223.	0.
3	358	9	0	3	2	3	8601.	8852.	8852.	9018.	251.	166.	251.	0.
2	362	4	5	2	2	13	8692.	10182.	10182.	10403.	1485.	220.	1490.	0.
2	364	0	11	2	1	14	8736.	10193.	10193.	10428.	1446.	235.	1457.	0.
1	366	20	10	1	1	8	8804.	9991.	9991.	10182.	1177.	191.	1187.	0.
2	368	20	10	2	2	13	8852.	10403.	10403.	10687.	1541.	284.	1551.	0.
3	372	19	12	3	1	1	8947.	8969.	8969.	9200.	10.	230.	22.	0.
3	373	5	3	3	2	2	8957.	9018.	9018.	9128.	58.	111.	61.	0.
2	374	0	9	2	1	14	8976.	10428.	10428.	10689.	1443.	262.	1452.	0.
3	374	22	11	3	2	2	8998.	9128.	9128.	9261.	119.	133.	130.	0.

4	378	13	0	4	1	0 9085.	9085. 8695. 9277.	0.	192. 0.	390.
2	379	17	0	2	2	13 9113.	10687.10687.10951.	1574.	264.1574.	0.
1	380	9	6	1	1	6 9129.	10182.10182.10302.	1047.	120.1053.	0.
2	384	22	9	2	1	12 9238.	10689.10689.10927.	1442.	238.1451.	0.
1	386	7	2	1	1	7 9271.	10302.10302.10426.	1029.	123.1031.	0.
2	387	5	5	2	1	13 9293.	10927.10927.11170.	1629.	243.1634.	0.
2	387	8	2	2	2	14 9296.	10951.10951.11150.	1653.	200.1655.	0.
2	392	0	6	2	2	15 9408.	11150.11150.11382.	1736.	232.1742.	0.
1	392	23	7	1	1	7 9431.	10426.10426.10639.	988.	213. 995.	0.
1	397	9	0	1	1	7 9537.	10639.10639.10766.	1102.	127.1102.	0.
3	398	14	0	3	2	0 9566.	9566. 9261. 9753.	0.	187. 0.	305.
3	399	14	0	3	1	0 9590.	9590. 9200. 9778.	0.	188. 0.	390.
3	400	4	7	3	2	1 9604.	9753. 9753. 9971.	142.	218. 149.	0.
4	400	14	0	4	1	0 9614.	9614. 9277. 9731.	0.	117. 0.	337.
2	405	22	8	2	1	13 9742.	11170.11170.11431.	1420.	261.1428.	0.
1	406	5	1	1	1	7 9749.	10766.10766.10879.	1016.	113.1017.	0.
2	406	23	7	2	2	14 9767.	11382.11382.11682.	1608.	300.1615.	0.
3	408	19	12	3	1	1 9811.	9823. 9778. 9992.	0.	169. 12.	45.
2	411	17	17	2	1	14 9881.	11431.11431.11699.	1533.	268.1550.	0.
2	412	14	0	2	2	15 9902.	11682.11682.11915.	1780.	234.1780.	0.
2	412	23	12	2	1	16 9911.	11699.11699.11965.	1776.	266.1788.	0.
3	413	7	5	3	2	1 9919.	9971. 9971.10093.	47.	121. 52.	0.
2	413	22	14	2	2	17 9934.	11915.11915.12157.	1967.	241.1981.	0.
3	416	5	1	3	1	1 9989.	9992. 9992.10146.	2.	154. 3.	0.
3	419	22	8	3	2	110078.	10093.10093.10266.	7.	174. 15.	0.
2	420	9	0	2	1	1610089.	11965.11965.12152.	1876.	187.1876.	0.
1	422	15	6	1	1	610143.	10879.10879.11025.	730.	147. 736.	0.
1	422	19	14	1	1	710147.	11025.11025.11253.	864.	228. 878.	0.
2	422	21	12	2	1	1710149.	12152.12152.12382.	1991.	230.2003.	0.
3	429	22	8	3	2	110318.	10326.10266.10567.	0.	241. 8.	60.
1	431	10	0	1	1	610354.	11253.11253.11455.	899.	202. 899.	0.
3	433	4	4	3	1	110396.	10400.10146.10568.	0.	168. 4.	254.
2	434	10	0	2	2	1510426.	12157.12157.12345.	1731.	189.1731.	0.
2	439	19	11	2	2	1510555.	12345.12345.12542.	1779.	197.1790.	0.
2	439	23	7	2	1	1610559.	12382.12382.12607.	1816.	225.1823.	0.
3	440	12	3	3	2	110572.	10575.10567.10759.	0.	184. 3.	8.
3	442	21	9	3	1	110629.	10638.10568.10806.	0.	168. 9.	70.
1	446	20	13	1	1	510724.	11455.11455.11674.	718.	219. 731.	0.
1	450	20	10	1	1	510820.	11674.11674.11838.	844.	165. 854.	0.
3	451	6	0	3	2	010830.	10830.10759.10998.	0.	168. 0.	71.
2	453	7	0	2	2	1510879.	12542.12542.12799.	1663.	257.1663.	0.
2	454	19	11	2	1	1610915.	12607.12607.12834.	1681.	227.1692.	0.
3	455	6	0	3	1	010926.	10926.10806.11071.	0.	145. 0.	120.
1	455	21	9	1	1	510941.	11838.11838.12055.	888.	216. 897.	0.
3	455	23	7	3	2	110943.	10998.10998.11144.	48.	146. 55.	0.
2	461	1	11	2	2	1511065.	12799.12799.13069.	1723.	270.1734.	0.
2	468	9	0	2	1	1411241.	12834.12834.13068.	1593.	234.1593.	0.
1	468	13	6	1	1	511245.	12055.12055.12199.	804.	145. 810.	0.
3	468	18	13	3	2	111250.	11263.11144.11455.	0.	192. 13.	119.

3	471	1	9	3	1	111305.	11314.	11071.	11399.	0.	85.	9.	243.
1	472	1	10	1	1	511329.	12199.	12199.	12347.	860.	148.	870.	0.
3	474	0	6	3	1	111376.	11399.	11399.	11558.	17.	159.	23.	0.
2	477	3	3	2	1	1311451.	13068.	13068.	13336.	1614.	269.	1617.	0.
2	479	2	4	2	2	1411498.	13069.	13069.	13327.	1567.	258.	1571.	0.
4	479	6	0	4	1	011502.	11502.	9731.	11695.	0.	193.	0.	1771.
3	480	0	7	3	2	111520.	11527.	11455.	11672.	0.	145.	7.	72.
3	480	5	2	3	1	211525.	11558.	11558.	11720.	31.	162.	33.	0.
1	482	23	10	1	1	511591.	12347.	12347.	12489.	746.	142.	756.	0.
1	485	2	10	1	1	611642.	12489.	12489.	12732.	837.	243.	847.	0.
1	487	1	5	1	1	611689.	12732.	12732.	12926.	1038.	194.	1043.	0.
3	487	12	2	3	2	111700.	11702.	11672.	11871.	0.	169.	2.	30.
2	488	4	2	2	2	1311716.	13327.	13327.	13590.	1609.	263.	1611.	0.
3	488	4	2	3	1	111716.	11720.	11720.	11961.	2.	241.	4.	0.
2	488	8	0	2	1	1411720.	13336.	13336.	13590.	1616.	254.	1616.	0.
2	492	8	0	2	2	1511816.	13590.	13590.	13808.	1774.	218.	1774.	0.
2	493	23	9	2	1	1611855.	13590.	13590.	13833.	1726.	243.	1735.	0.
3	495	4	6	3	2	111884.	11890.	11871.	12131.	0.	241.	6.	19.
3	497	17	0	3	1	111945.	11961.	11961.	12157.	16.	196.	16.	0.
3	498	0	6	3	2	211952.	12131.	12131.	12247.	173.	116.	179.	0.
3	498	15	0	3	1	211967.	12157.	12157.	12278.	190.	122.	190.	0.
3	498	17	0	3	2	311969.	12247.	12247.	12390.	278.	144.	278.	0.
3	500	5	1	3	1	412005.	12278.	12278.	12462.	272.	184.	273.	0.
1	500	12	3	1	1	612012.	12926.	12926.	13110.	911.	184.	914.	0.
2	500	20	10	2	2	1512020.	13808.	13808.	14104.	1778.	296.	1788.	0.
2	501	20	10	2	1	1612044.	13833.	13833.	14047.	1779.	214.	1789.	0.
1	503	22	8	1	1	612094.	13110.	13110.	13232.	1008.	122.	1016.	0.
3	503	23	7	3	2	512095.	12390.	12390.	12582.	288.	192.	295.	0.
2	504	12	0	2	1	1712108.	14047.	14047.	14335.	1939.	289.	1939.	0.
3	504	21	10	3	1	612117.	12462.	12462.	12632.	335.	169.	345.	0.
2	506	20	13	2	2	1612164.	14104.	14104.	14362.	1927.	258.	1940.	0.
2	511	5	1	2	1	1712269.	14335.	14335.	14598.	2065.	263.	2066.	0.
1	511	20	10	1	1	612284.	13232.	13232.	13382.	938.	150.	948.	0.
4	512	12	3	4	1	112300.	12303.	11695.	12465.	0.	162.	3.	608.
1	515	17	1	1	1	612377.	13382.	13382.	13546.	1004.	164.	1005.	0.
4	516	15	4	4	1	112399.	12465.	12465.	12585.	62.	120.	66.	0.
4	518	12	0	4	1	212444.	12585.	12585.	12742.	141.	157.	141.	0.
1	519	12	0	1	1	712468.	13546.	13546.	13715.	1078.	169.	1078.	0.
1	520	17	6	1	1	712497.	13715.	13715.	13836.	1212.	121.	1218.	0.
1	522	16	0	1	1	812544.	13836.	13836.	14022.	1292.	186.	1292.	0.
2	522	21	9	2	2	1512549.	14362.	14362.	14622.	1804.	260.	1813.	0.
3	523	17	0	3	2	112569.	12582.	12582.	12751.	13.	169.	13.	0.
2	524	3	3	2	1	1612579.	14598.	14598.	14815.	2016.	216.	2019.	0.
2	524	15	0	2	2	1712591.	14622.	14622.	14839.	2031.	217.	2031.	0.
3	525	16	0	3	1	112616.	12632.	12632.	12750.	16.	119.	16.	0.
3	531	20	14	3	2	112764.	12778.	12751.	13019.	0.	241.	14.	27.
3	532	7	4	3	1	212775.	12779.	12750.	12924.	0.	145.	4.	29.
3	532	18	17	3	1	112786.	12924.	12924.	13097.	121.	173.	138.	0.
4	536	4	2	4	1	112868.	12870.	12742.	13024.	0.	154.	2.	128.
2	536	20	10	2	1	1512884.	14815.	14815.	15126.	1921.	312.	1931.	0.

3	539	7	0	3	2	112943.	13019.13019.13207.	76.	188.	76.	0.
3	540	2	5	3	1	212962.	13097.13097.13219.	130.	122.	135.	0.
2	540	10	0	2	2	1612970.	14839.14839.15067.	1869.	229.	1869.	0.
3	540	12	0	3	2	312972.	13207.13207.13355.	235.	149.	235.	0.
2	546	6	0	2	2	1513110.	15067.15067.15319.	1957.	251.	1957.	0.
2	547	1	5	2	1	1613129.	15126.15126.15328.	1992.	201.	1997.	0.
3	548	12	3	3	1	213164.	13219.13219.13422.	52.	203.	55.	0.
2	548	18	12	2	2	1713170.	15319.15319.15535.	2137.	216.	2149.	0.
1	548	23	7	1	1	613175.	14022.14022.14167.	840.	144.	847.	0.
3	549	2	4	3	2	313178.	13355.13355.13446.	173.	91.	177.	0.
2	549	9	0	2	1	1813185.	15328.15328.15558.	2143.	231.	2143.	0.
3	551	5	1	3	1	213229.	13422.13422.13639.	192.	217.	193.	0.
3	552	6	1	3	2	313254.	13446.13446.13639.	191.	193.	192.	0.
3	553	17	15	3	2	413289.	13639.13639.13814.	335.	174.	350.	0.
3	554	8	1	3	1	513304.	13639.13639.13833.	334.	194.	335.	0.
2	554	16	17	2	2	1913312.	15535.15535.15754.	2206.	219.	2223.	0.
2	555	19	15	2	1	1813339.	15558.15558.15851.	2204.	292.	2219.	0.
2	557	2	10	2	2	1913370.	15754.15754.16045.	2374.	290.	2384.	0.
3	557	18	18	3	2	513386.	13814.13814.13957.	410.	143.	428.	0.
3	560	13	2	3	1	413453.	13833.13833.14071.	378.	237.	380.	0.
2	567	0	10	2	1	1813608.	15851.15851.16072.	2233.	221.	2243.	0.
2	567	8	2	2	2	1913616.	16045.16045.16306.	2427.	262.	2429.	0.
3	567	13	0	3	2	513621.	13957.13957.14099.	336.	142.	336.	0.
3	570	19	11	3	1	413699.	14071.14071.14190.	361.	119.	372.	0.
3	572	0	6	3	2	513728.	14099.14099.14247.	365.	148.	371.	0.
2	573	0	6	2	1	2013752.	16072.16072.16354.	2314.	282.	2320.	0.
2	573	6	0	2	2	2113758.	16306.16306.16553.	2548.	246.	2549.	0.
4	575	16	14	4	1	113816.	13830.13024.13999.	0.	169.	14.	806.
1	578	3	6	1	1	213875.	14167.14167.14386.	286.	219.	292.	0.
1	581	7	5	1	1	313951.	14386.14386.14556.	430.	171.	435.	0.
4	581	14	0	4	1	113958.	13999.13999.14197.	41.	198.	41.	0.
1	585	1	5	1	1	314041.	14556.14556.14743.	510.	187.	515.	0.
2	585	13	3	2	1	1914053.	16354.16354.16543.	2298.	189.	2301.	0.
2	586	7	0	2	1	2014071.	16543.16543.16759.	2472.	216.	2472.	0.
3	586	23	7	3	1	214087.	14190.14190.14382.	96.	192.	103.	0.
4	587	1	5	4	1	114089.	14197.14197.14382.	103.	186.	108.	0.
1	589	4	4	1	1	414140.	14743.14743.14865.	599.	122.	603.	0.
3	590	10	0	3	2	214170.	14247.14247.14482.	77.	235.	77.	0.
4	591	17	5	4	1	114201.	14382.14382.14580.	176.	198.	181.	0.
2	592	2	9	2	2	2014210.	16553.16553.16812.	2334.	259.	2343.	0.
3	593	11	1	3	1	214243.	14382.14382.14508.	138.	126.	139.	0.
1	594	22	8	1	1	414278.	14865.14865.14959.	579.	94.	587.	0.
3	595	17	0	3	2	214297.	14482.14482.14719.	185.	237.	185.	0.
3	595	19	11	3	1	314299.	14508.14508.14729.	198.	220.	209.	0.
2	596	11	4	2	1	2114315.	16759.16759.17001.	2440.	242.	2444.	0.
2	599	22	8	2	2	2014398.	16812.16812.17047.	2406.	235.	2414.	0.
3	603	4	6	3	2	314476.	14719.14719.14939.	237.	220.	243.	0.
4	603	4	6	4	1	114476.	14580.14580.14747.	98.	167.	104.	0.
3	603	15	0	3	1	314487.	14729.14729.14914.	242.	185.	242.	0.
3	603	21	13	3	1	414493.	14914.14914.15083.	408.	169.	421.	0.

1	605	0	12	1	1	414520.	14959.14959.15062.	427.	103. 439.	0.
3	610	10	0	3	2	414650.	14939.14939.15055.	289.	116. 289.	0.
1	612	15	4	1	1	414703.	15062.15062.15175.	355.	113. 359.	0.
2	613	12	0	2	1	1914724.	17001.17001.17217.	2277.	216.2277.	0.
3	613	18	14	3	2	314730.	15055.15055.15177.	311.	122. 325.	0.
3	613	21	11	3	1	414733.	15083.15083.15272.	339.	189. 350.	0.
3	614	7	2	3	2	514743.	15177.15177.15345.	432.	168. 434.	0.
1	615	14	0	1	1	414774.	15175.15175.15274.	401.	99. 401.	0.
1	620	14	1	1	1	414894.	15274.15274.15472.	379.	198. 380.	0.
3	620	14	1	3	1	614894.	15272.15272.15424.	377.	152. 378.	0.
1	622	5	1	1	1	514933.	15472.15472.15610.	538.	139. 539.	0.
3	622	15	2	3	2	514943.	15345.15345.15487.	400.	142. 402.	0.
2	623	18	12	2	2	1814970.	17047.17047.17310.	2065.	264.2077.	0.
3	625	4	4	3	1	615004.	15424.15424.15657.	416.	233. 420.	0.
3	626	0	9	3	2	715024.	15487.15487.15681.	454.	195. 463.	0.
3	626	9	0	3	1	815033.	15657.15657.15730.	624.	73. 624.	0.
2	627	0	10	2	1	1915048.	17217.17217.17507.	2159.	290.2169.	0.
1	631	7	0	1	1	415151.	15610.15610.15758.	459.	148. 459.	0.
2	632	2	4	2	2	1815170.	17310.17310.17552.	2136.	242.2140.	0.
4	635	18	12	4	1	115258.	15270.14747.15415.	0.	145. 12.	523.
2	639	6	4	2	1	1715342.	17507.17507.17702.	2161.	195.2165.	0.
2	643	16	0	2	2	1815448.	17552.17552.17791.	2104.	238.2104.	0.
3	649	14	18	3	2	215590.	15681.15681.15824.	73.	143. 91.	0.
2	652	15	0	2	1	1715663.	17702.17702.17892.	2039.	190.2039.	0.
1	654	11	2	1	1	115707.	15758.15758.15895.	49.	137. 51.	0.
2	654	23	7	2	2	1815719.	17791.17791.18030.	2065.	240.2072.	0.
3	655	16	0	3	1	015736.	15736.15730.15881.	0.	145. 0.	6.
4	657	2	4	4	1	115770.	15774.15415.15928.	0.	154. 4.	359.
2	662	23	10	2	1	1715911.	17892.17892.18081.	1971.	190.1981.	0.
3	663	2	8	3	2	115914.	15922.15824.16043.	0.	121. 8.	98.
1	664	13	0	1	1	015949.	15949.15895.16091.	0.	142. 0.	54.
2	665	6	6	2	2	1815966.	18030.18030.18228.	2058.	198.2064.	0.
3	665	22	14	3	1	115982.	15996.15881.16165.	0.	169. 14.	115.
2	666	4	2	2	1	1915988.	18081.18081.18294.	2091.	213.2093.	0.
4	666	20	10	4	1	116004.	16014.15928.16169.	0.	155. 10.	86.
1	670	20	10	1	1	116100.	16110.16091.16279.	0.	169. 10.	19.
3	671	17	13	3	2	116121.	16134.16043.16329.	0.	195. 13.	91.
4	672	18	13	4	1	116146.	16169.16169.16328.	10.	158. 23.	0.
1	676	3	8	1	1	116227.	16279.16279.16456.	44.	177. 52.	0.
2	676	15	0	2	2	1816239.	18228.18228.18443.	1989.	215.1989.	0.
1	677	15	0	1	1	216263.	16456.16456.16596.	193.	140. 193.	0.
4	678	18	12	4	1	116290.	16328.16328.16519.	26.	191. 38.	0.
4	679	0	6	4	1	216296.	16519.16519.16671.	217.	152. 223.	0.
2	681	9	0	2	1	1816353.	18294.18294.18568.	1941.	274.1941.	0.

FIRST 213. ARRIVALS IGNORED.

TYPE	NO.ARRIV.	AV.WT.	TOT.IDLETIME	%IDLE TIME	AV SERVICE	MAXQ
1.00	45.00	745.26	72.85	0.90	160.62	8.00
2.00	72.00	1902.34	0.00	0.00	240.13	21.00
3.00	77.00	162.27	2172.14	26.79	170.09	8.00
4.00	19.00	51.01	5086.57	62.74	165.80	2.00

TYPE=1 QUEUE LENGTHS

0	1
1	3
2	2
3	2

4	7
5	7
6	11
7	8
8	4

TYPE=2 QUEUE LENGTHS

0	0
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0
11	1
12	3
13	7
14	8
15	11
16	10
17	9
18	10
19	7
20	4
21	2

TYPE=3 QUEUE LENGTHS

0	5
1	27
2	14
3	11
4	8
5	7
6	3
7	1
8	1

TYPE=4 QUEUE LENGTHS

0	4
1	13
2	2

TYPE=1 WAITING TIMES

0-11.99	2	48-59.99	2	192-203.99	1
288-299.99	1	348-359.99	1	372-383.99	1
396-407.99	1	432-443.99	2	456-467.99	1
504-515.99	1	528-539.99	1	576-587.99	1
600-611.99	30				

TYPE=2 WAITING TIMES

600-611.99	72

TYPE=3 WAITING TIMES

0-11.99	17				
12-23.99	11	24-35.99	1	48-59.99	3
60-71.99	1	72-83.99	2	84-95.99	1
96-107.99	1	120-131.99	1	132-143.99	3
144-155.99	1	168-179.99	2	180-191.99	2
192-203.99	2	204-215.99	1	228-239.99	2
240-251.99	3	264-275.99	2	276-287.99	1
288-299.99	3	324-335.99	3	336-347.99	1
348-359.99	2	360-371.99	2	372-383.99	2
396-407.99	1	408-419.99	1	420-431.99	2
432-443.99	1	456-467.99	1	600-611.99	1

TYPE=4 WAITING TIMES

0-11.99	8	12-23.99	3	36-47.99	2
60-71.99	1	96-107.99	2	132-143.99	1
180-191.99	1	216-227.99	1		

TYPE=1 IDLE TIMES

0-11.99	43	12-23.99	1	48-59.99	1

TYPE=2 IDLE TIMES

0-11.99	72

TYPE=3 IDLE TIMES

0-11.99	59	12-23.99	1	24-35.99	3
36-47.99	1	48-59.99	1	60-71.99	3
84-95.99	1	96-107.99	1	108-119.99	3
240-251.99	1	252-263.99	1	300-311.99	1
384-395.99	1				

TYPE=4 IDLE TIMES

0-11.99	9	72-83.99	1	84-95.99	1
120-131.99	1	336-347.99	1	348-359.99	1
384-395.99	1	516-527.99	1	600-611.99	1
804-815.99	1	1200-1211.99	1		

6.5 Matching of Operations on Land Side

Some parts of the port system are linked in that every ton of cargo which passes through one of them passes through the others. The most important links are between the ship cargo - handling system and storage, and later, between storage and onward transport. The first pair of linked operations, unloading from ship and placing it in storage must be matched on an hourly basis; otherwise one operation will have to wait for the other, or goods will pile up on the operational area and cause congestion. To find out if they are matched it is necessary to know the hourly capabilities of each operation separately. The hourly capacity of the crane or hook can be determined from the berth capacity (tons/year, see Table 2.2 of Chapter 2), for example, for general cargo it will be 300,000/(365 x 24) = 34.24 tons/hour, for containers it will be 500,000/(365 x 24) = 57 tons/hour and so on.

Looking at figure 6.3 where the hook capacity is, say 12 tons per gang-hour, and the transfer capacity is, say 18 tons per gang-hour, it becomes clear that 3 gangs are required to feed the hook and 2 gangs for transferring the cargo to the shed for general cargo and 3 gangs for the transfer of containers.

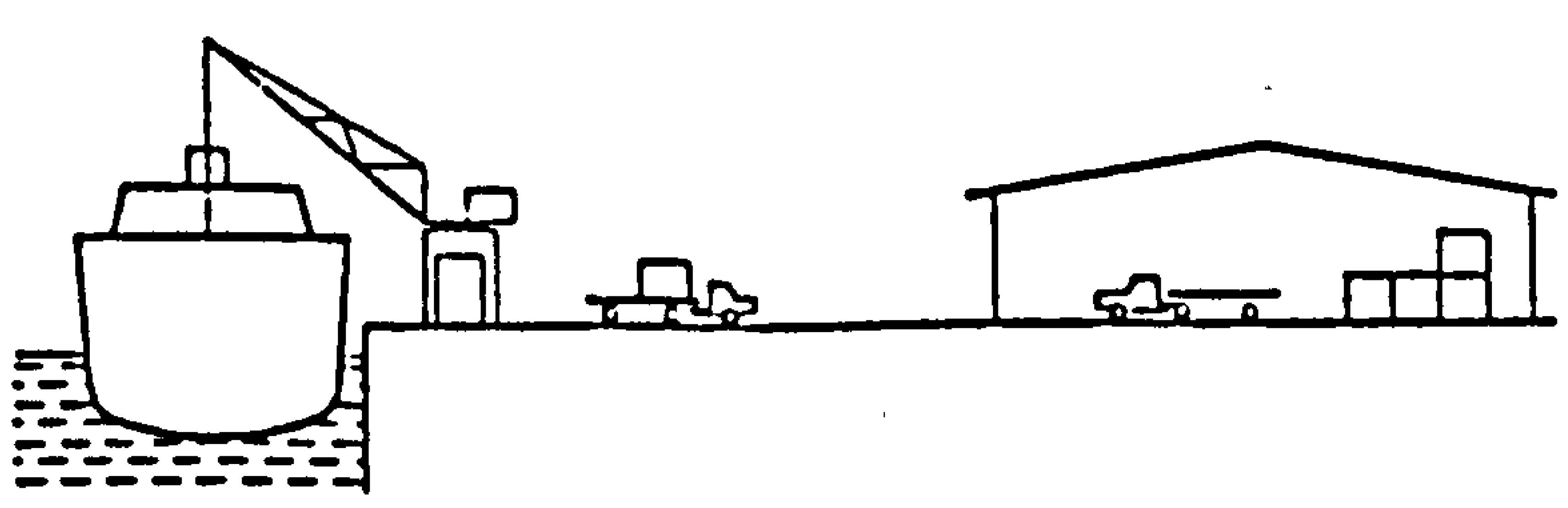


Figure 6.3 Combined capacity of ship cargo-handling system and transfer system

Retrieving cargo from storage for onward transport cannot be matched with the placing of cargo in storage either on hourly basis or even on a daily basis. Customs clearance and delivery formalities take time, and their duration may vary considerably. But the capacity to despatch cargo from the transit storage areas must match the flow of cargo from quay to storage on, say, a weekly basis; otherwise transit sheds and open storage areas will become overfilled and serious congestion will result.

The storage area depends on how much cargo will be loaded and transferred directly to intermediate depots and final destinations by rail, road and possibly river transport and how much will be stored for varying periods of time.

The maximum cargo to be stored may be found as a function of the number of calls, quantity of cargo per call and storage time. (Slettemark 1975) has developed graphs for the storage utilisation in tons per square metre per year for conventional cargo, pallets and containers (see figure 6.4). The necessary storage area was assumed to be

conventional cargo	10 m^2/ton
pallets	5 m^2/ton
containers	7-10 m^2/ton

These figures also include space for transport lanes within the storage area. Figure 6.4 shows an example of storage utilisation in tons per square metre per year assuming 370 tons of cargo per call unloaded plus loaded. It may be noted that the utilisation of the storage area, measured as tons per square metre per year increases at a decreasing rate as berth throughput goes up. For a given throughput, utilisation increases as storage time decreases.

An example may show how figure 6.4 may be used for calculating the necessary storage area. Assume a berth throughput of 70,000 tons a year, a maximum storage time of 15 days of inbound cargo and 4 days for outbound. The necessary storage area may then be calculated by using the middle curve of Figure 6.4.

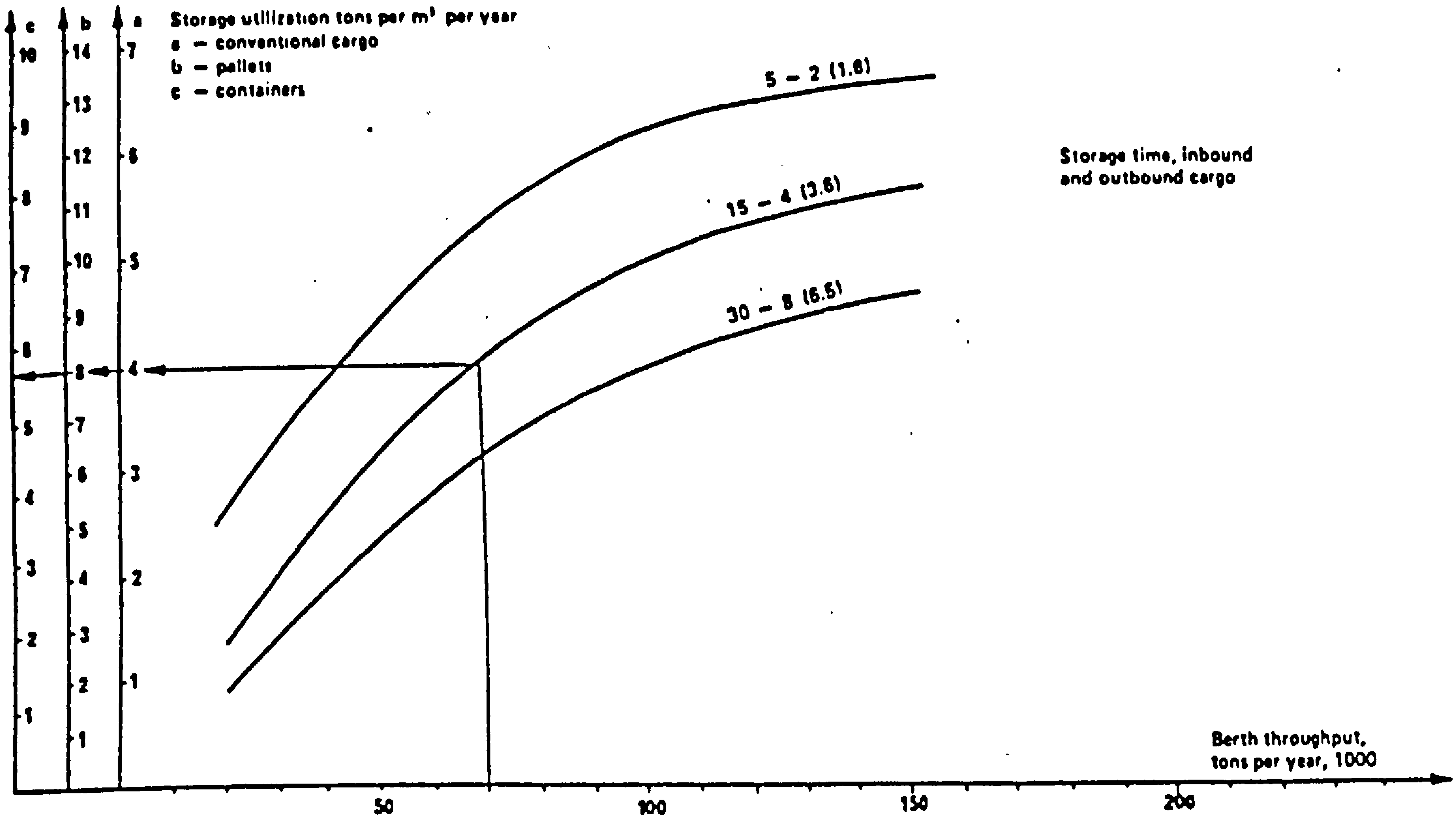


Figure 6.4 Storage utilisation depending on berth throughput, tons per year

Conventional cargo	70,000/4 = 17500 m^2
Pallets	70,000/8 = 8500 m^2
Containers (assuming 7 m^2/ton)	70,000/5.7 = 12280 m^2

In his paper he refers to previous work (Slettemark 1974) where similar figures are worked for other sizes of ship loads. (Jansson 1984, see section 1.2.1) adopts a more elementary approach, and from his figure where the expansion path for the number of service stations, he supposes that the mean storage time is so many times longer than the expected service time, if for example it is seven times longer (one week as opposed to one day), this means that the total storage time of cargo is also seven times greater than the total service time of ships and hence multiplying the service time by 7, locating it on the horizontal scale, the number of transit storage stations is obtained immediately on the vertical scale.

An alternative approach is obviously simulation. Suppose for example, that the ships discharge rate for a group of general cargo berths for 30 days, the amount of cargo loaded directly to rail and trucks and the amount transferred (withdrawn) from the stores is as shown in the hypothetical Table in the next page.

Assuming that the hypothetical figures are for a typical month, the following conclusions can be drawn. In order to avoid delaying the ships discharge, and looking at the last column, a storage area should be provided to accommodate at least the maximum amount of cargo left in storage (9100 tons, day 29). If 10 m^2 for the storage of every ton is required, then the storage area should at least be 91,000 x 10 = 91,000 m^2.

On the other hand, if at all possible, more frequent withdrawals from the stores would reduce the required storage area considerably.

Since the discharge of cargo is governed by the arrivals and service time of ships which is known from the simulation, the observed distribution for the discharge of cargo is registered and could fit any of the theoretical distributions or it could be obtained empirically. A similar distribution can be obtained for the cargo transferred from stores. Assuming that the amount of cargo transferred by rail and road is relatively constant, then it will be a simple matter simulating the arrival of cargo (discharged from ships) and departures of cargo (withdrawal from stores) using the two distributions above very similar to the arrivals and services of ships respectively. From the simulation the maximum amount of cargo left in the stores at any period could be obtained for which the required storage area could be worked out.

In the operations of a port, the various subsystems function together so that the effectiveness of one subsystem affects the operations of the others. The goods can be thought of as a liquid passing through the various subsystems which can be thought of as a series of sections of a pipe of four different diameters as illustrated in figure 6.5.

Day	Discharge	Rail	Road	Stored	Withdrawn	Left in Stores
1	22	5	6	11	--	11
2	18	4	5	9	--	20
3	20	4	5	11	--	31
4	21	5	4	12	--	43
5	22	5	7	10	--	53
6	20	5	6	9	32	30
7	22	4	4	14	--	44
8	19	5	4	10	--	54
9	22	6	6	10	20	44
10	18	5	5	8	--	52
11	21	5	5	11	21	42
12	20	4	7	9	--	51
13	19	5	6	8	--	59
14	18	4	4	10	20	49
15	17	5	4	8	8	49
16	20	4	6	10	--	59
17	19	5	5	9	--	68
18	21	5	6	10	--	78
19	23	5	5	13	30	61
20	22	4	4	14	15	60
21	20	5	6	9	--	69
22	20	5	5	10	12	67
23	21	4	5	12	10	69
24	19	5	6	8	--	77
25	19	4	4	11	21	67
26	23	5	6	12	--	79
27	21	5	5	11	15	75
28	22	4	6	12	10	77
29	24	5	5	14	--	91
30	20	5	5	10	11	90

Cargo throughput for a group of general cargo berths (100 tons)

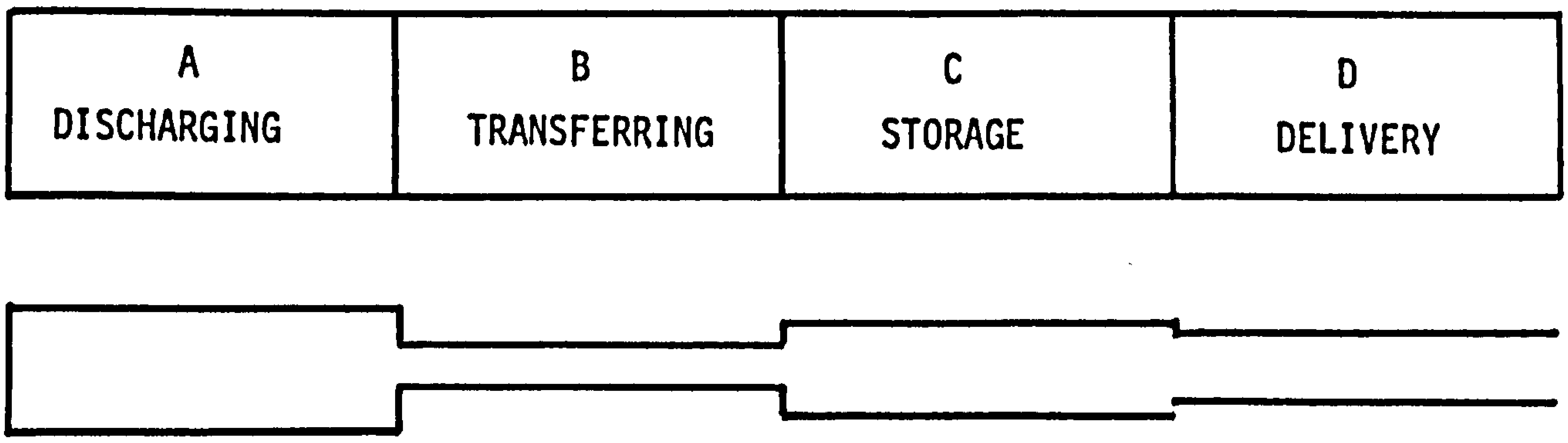


Figure 6.5 Flow of Goods through Ports

The maximum throughput through this system is determined by the capacity of the narrowest section, B, which forms a bottleneck. It is obviously not possible to increase the overall capacity by widening any other section before making improvements to section B. The only way to increase the overall capacity is to increase the capacity of section B to that of the next largest capacity, section D. Then, if justified, further improvements in the total capacity will require an equal increase in the capacities of both sections B and D.

Once the discharge capacity for each class of cargo is known, the transfer capacity can be worked out to match the discharging capacity as illustrated earlier in this section. Since the berth throughput is known, what is required is the maximum storage time for each class of cargo. As soon as this is decided, the necessary storage area may then be calculated by using the curves shown in figure 6.4 as illustrated earlier or more accurately through simulation.

6.6 Inland Transport

In this section a discussion on how goods are to be moved outside the port boundaries (inland transport) will be provided.

The starting point is to consider what the modal-split of the traffic in question will be, that is, what proportion will come and go by road and by rail. In judging whether the modal-split is likely to change, the main factor will be the extent to which the trunk road access and internal road sidings are available at the shippers premises (factories, warehouses).

For each main traffic class (break-bulk cargo, containers, etc.), it is next necessary to forecast its own modal-split and to link this with the future distribution system. The system can be considered as a series of connecting tanks with taps which have to be shut off when only one tank becomes full as illustrated in figure 6.6.

In accordance with this figure, if any one of the stores (port storage, inland depot or user's stocks) becomes full, then in the short-term the normal solution is to stop the flow into it. This soon causes the preceeding store to fill up. As regards the port import storage there is the difficulty in turning off the ship discharge tap when there is a hold-up in the system and consequently the port feels the overload. In the longer term, the solution may be to increase the size of the inland depot, but there is not often the possibility of increasing the outflow from any store since this would need to be passed down the line and can only end with increased consumption which is not a transport solution.

Figure 6.6 illustrates the chain reaction involved, but in reality there will normally be a branching network of depots and transport connections, all of which taken together act to clear port storage as shown in figure 6.7. The total capacity of all these must be made sufficient to handle the total ship discharge rate.

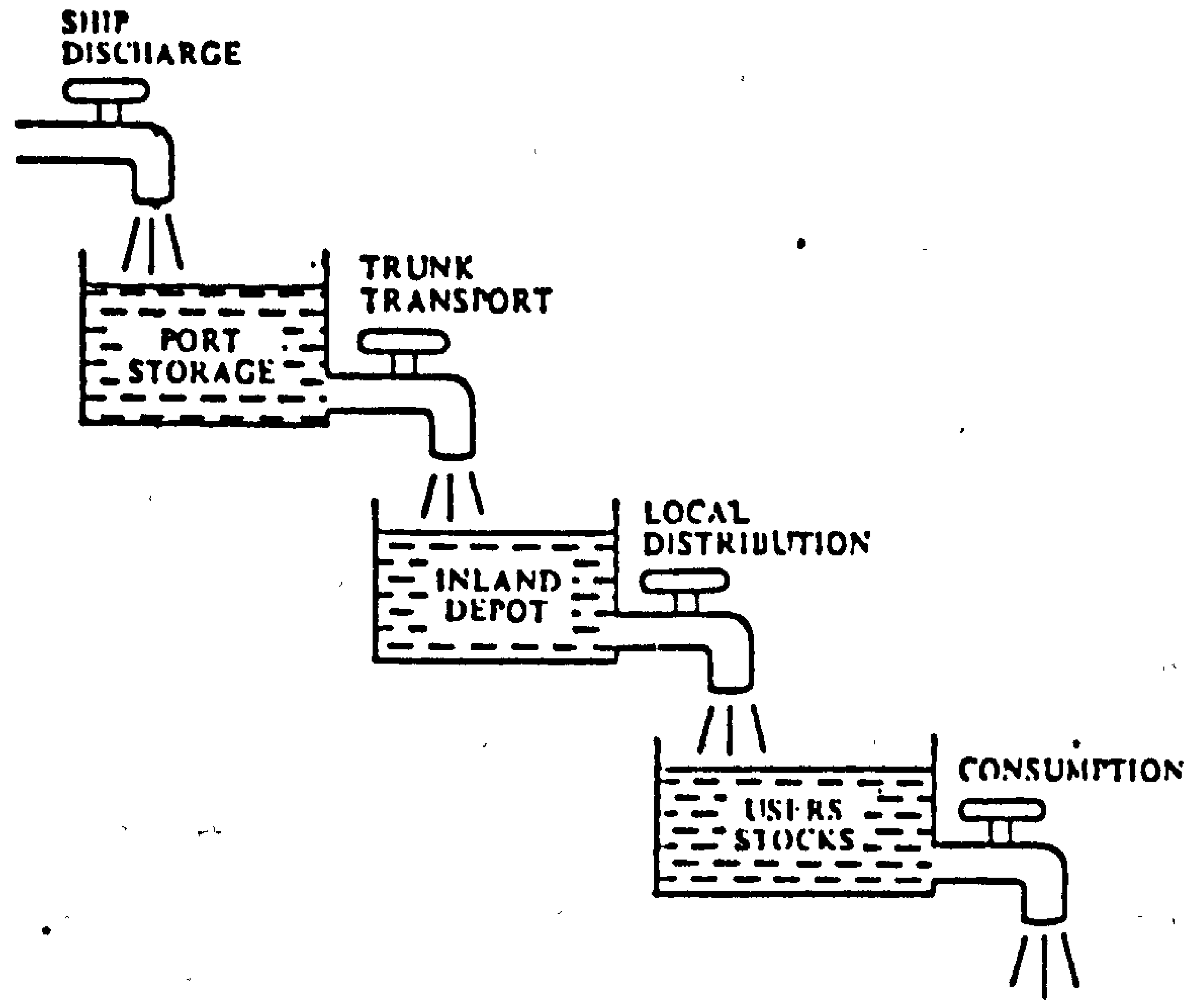


Figure 6.6 The Import Flow

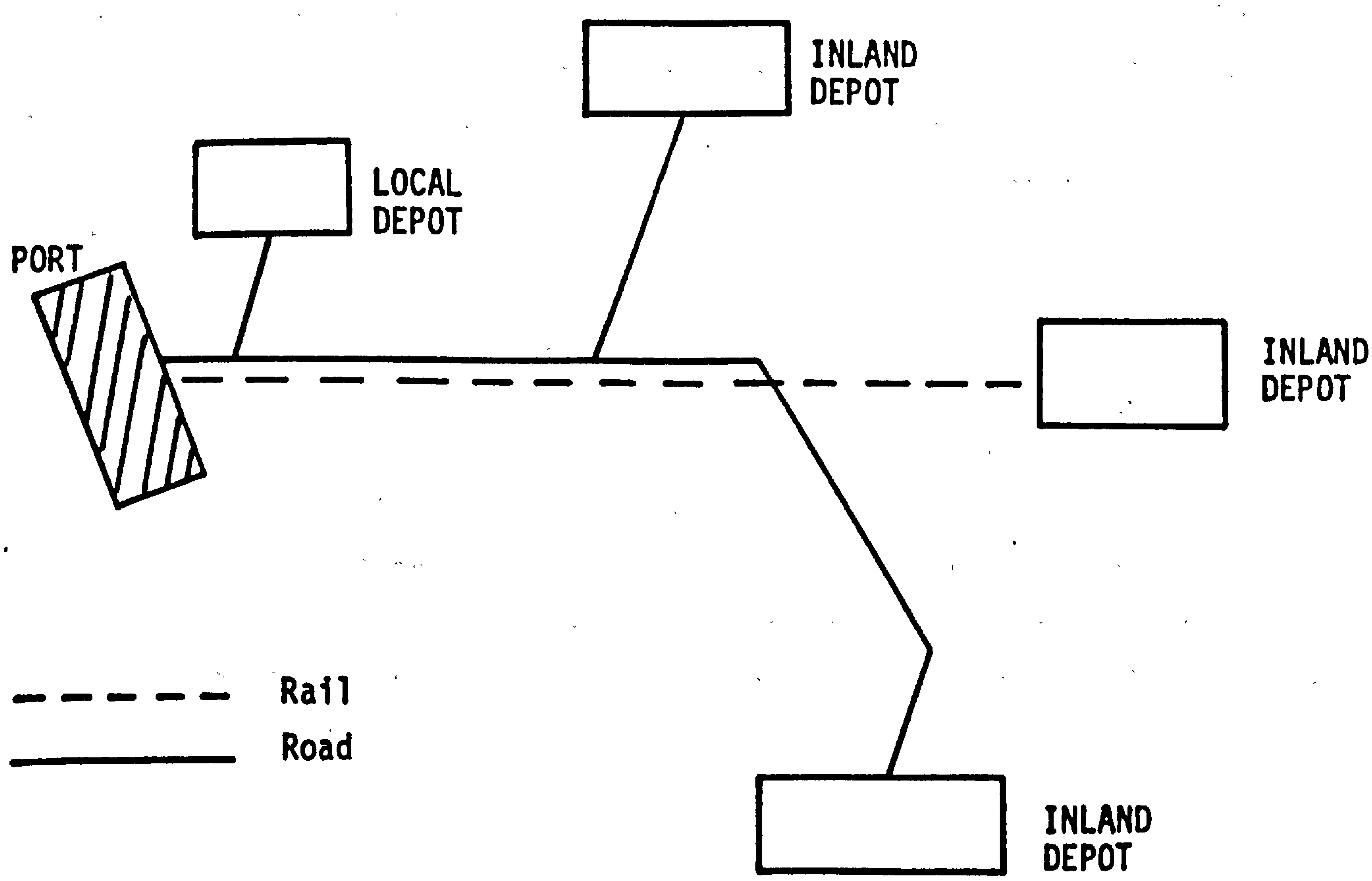


Figure 6.7 Inland Transport Network

The second tap shown in Figure 6.6 controls the flow of goods out of the port storage. Import consignments are normally cleared from the ports only when duties and charges have been made, documentary formalities have been completed, customs clearance has been given and the consignee wants the goods.

When checking that proper provision is being made for the land transport capacity needed to match the forecast of the port throughput, the vehicle fleet and the route capacity required should be considered. Both of these are heavily dependent on the inland side distribution pattern. It is not sufficient to calculate the number and type of vehicles which will be needed per day to bring or take away the daily loading and discharge tonnages. This figure will show what the handling, marshalling and administrative needs are but they give little indication of the transport problem because they leave out the vehicle journey time, for example, to clear 1000 tons a day to the adjacent city area, say Nasiriyah (see maps in Chapter 2), may call for 42 local delivery vehicles of eight-ton capacity fitting in an average of three round trips a day, whilst to clear the same 1000 tons to an inland depot 600 kilometres from the port say to Baghdad may call for about 100 vehicles of 20-ton capacity taking two days to make each round trip. The distribution pattern and the route capacity determine not only the number of vehicles needed but also the type of vehicle.

When looking several years ahead, one of the major effects, which has strong repercussions on the port, is the need to introduce intermediate depots to separate trunk-road transport from local distribution (UNCTAD 1978). This effect is illustrated in Figure 6.8. When there is a change from the one-leg pattern to the two-leg pattern the type of vehicle serving the port is likely to increase in size and cost and will therefore demand faster servicing in port to match its shorter journey time in order to reduce unit costs.

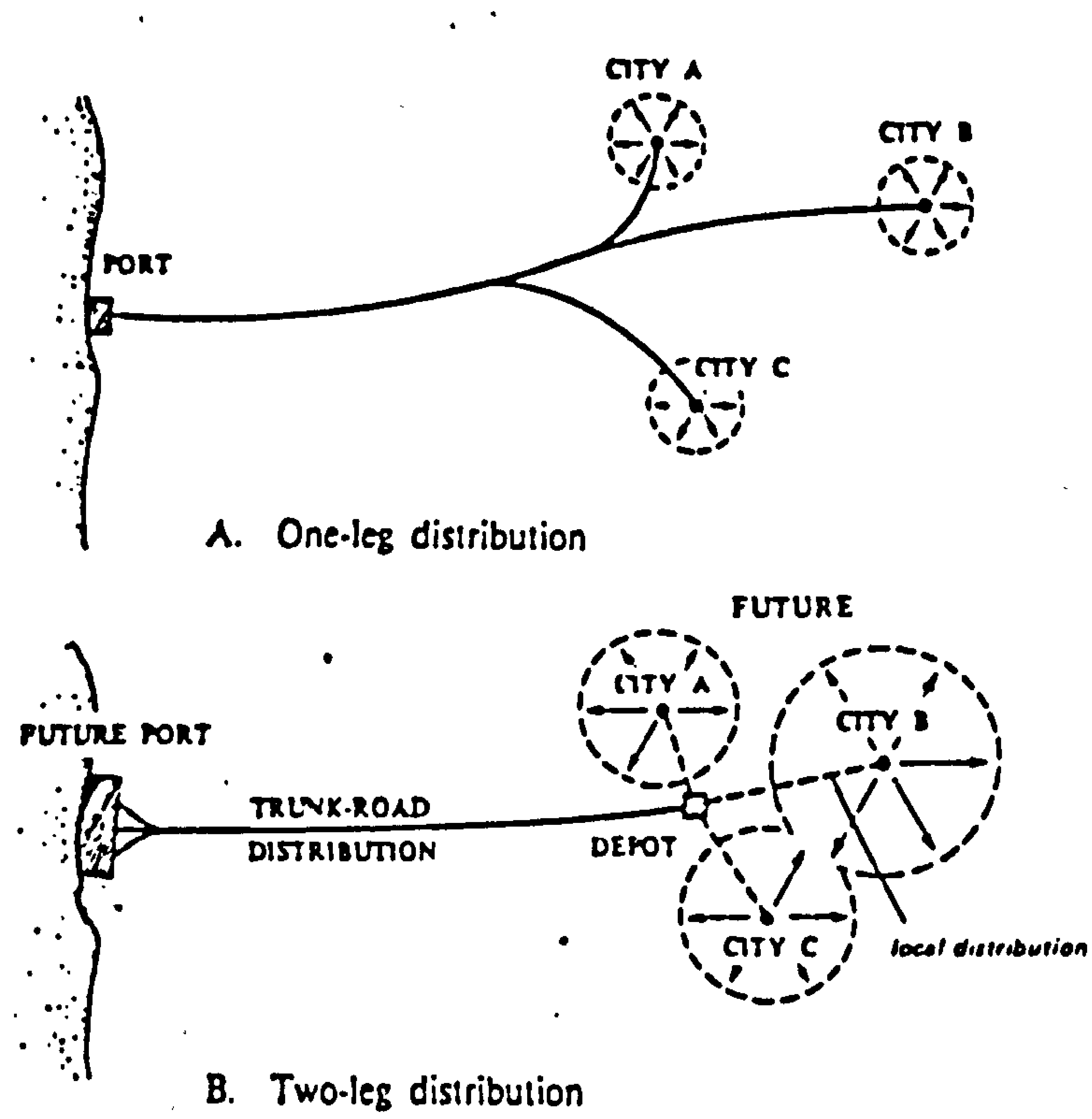


Figure 6.8 The effect of introducing intermediate depots

The simulation program was written in BASIC and run on the department's BBC microcomputer. Using a microcomputer is the strategy of the technique being used for the following reasons:-

1. In writing a simulation program one has to devise and write all the routines necessary to mimic and control queueing, create and destroy ships, advance time, schedule and control the execution by the computer of each task due in the correct sequence, perform pseudo-random drawings from various statistical distribution and maintain statistical results. This is a laborious programming task, is very liable to errors and therefore requires substantial testing and verification of the program which needs hundreds of runs before the simulation can be performed. Making these initial runs can be very costly if a large computer is used while they cost virtually nothing on the microcomputer. In addition to this, yet more hundreds or thousands of simulation runs are required to obtain the desired results. Therefore the microcomputer provides a cheap means for such studies.

2. While large computers are available in most of the organisations in developed countries, this is not the case in the developing ones, and since the microcomputers cost very little and are cheap to run, they can be easily acquired and used in the developing countries.

3. The use of the microcomputer enables the planner or the researcher to follow the execution of the program, spot the mistakes as they arise and rectify them, and make the runs at any desired time, while using a large computer which is shared by many people might be time consuming when waiting for the results of each run, especially in the initial stages of program preparation.

Finally, the same program that is written and executed on the microcomputer can be run on a large computer if the need does arise.

In what follows the simulation results are shown in Tables 6.11 to 6.39, together with the data input for each one. The results are analysed in Chapter 7, and in Chapter 8 an investment model is developed to arrive at the optimum number of berths for each class or cargo at any future time period.

TABLE 6-11: BASRA 1979 - BO 12 H/D

Type	QS	NSA	ASL	BC	µ	σ	NB	AWT	%IT	%IT/B	AST	MQL	>24H	>120H	>24H
1. GC	262,789	491	5,350	300,000	156	40	15	13.74	301.30	20.08	160.34	50	78	-	-
2. Grain	1,610,521	81	19,883	400,000	435	100	2	235.26	10.91	5.45	453.79	4	65	52	33
3. Oil	137,045	15	9,136	400,000	200	40	1	29.07	68.92	68.92	221.71	1	1	1	-
4. Urea	276,286	39	7,084	400,000	155	34	1	101.39	32.32	32.32	161.63	2	23	12	5

TABLE 6-12: UM QASR 1979 - BO 12 H/D

1. GC	899,961	165	5,454	300,000	159	36	4	65.92	49.77	12.44	162.45	8	106	33	3
2. Cont.	296,874	124	2,394	500,000	42	7	1	70.70	33.14	33.14	45.86	6	67	29	2
3. Cement	162,491	20	8,125	300,000	237	43	1	48.67	45.35	45.35	247.72	1	5	3	-
4. Sulphur	601,498	53	11,349	300,000	331	54	3	58.98	81.20	27.06	328.69	4	20	13	2

TABLE 6-13: KHOR AL-ZUBAIR 1979 - BO 12 H/D

1. Fertil.	146,709	25	5,868	550,000	94	24	1	19.11	73.47	73.47	102.32	2	5	1	-

KEY TO COLUMN HEADINGS: TABLES 6-11 - 6-39

INPUT

Type	-	Type of cargo
QS	-	Quantity serviced
NSA	-	Number of ships arriving
ASL	-	Average ship load
BC	-	Berth capacity per year
μ	-	Mean service time
σ	-	Standard deviation
NB	-	Number of berths simulated

OUTPUT

AWT	-	Average waiting time per ship
%IT	-	Total idle time for the group of berths for each class of cargo
%IT IB	-	Percentage idle time per berth
AST	-	Average service time during simulation
MQL	-	Maximum queue length reached
>24H	-	Number of ships waiting over 24 hours
>120H	-	Number of ships waiting over 120 hours
>240H	-	Number of ships waiting over 240 hours

TABLE 6.14 BASRA 1985 MLF B.O 12H/D

	TYPE	Q.S	N.S.A	A.S.L	B.C	μ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1.	G.C	3,193,742	550	5,807	300,000	169	43	15	10.28	360.88	24.05	173.69	7	92	-	-
2.	GRAIN	1,478,460	74	19,979	400,000	438	100	7	6.04	340.92	48.70	441.54	2	1	-	-
3.	OIL	203,371	21	9,684	400,000	212	42	5	6.42	446.60	88.92	236.53	1	-	-	-
4.	SUGAR	415,840	42	9,901	400,000	217	43	6	4.37	499.08	83.18	224.38	2	-	-	-
1.		3,456,242	600	5,760	300,000	168	43	15	11.79	327.07	21.80	173.13	10	102	-	-
2.								6	19.93	208.06	34.81	447.67	2	16	4	-
3.								4	6.35	337.28	84.32	224.48	1	-	-	-
4.								5	9.51	390.40	78.08	226.60	2	3	-	-
1.		3,718,742	650	5,721	300,000	167	43	15	16.42	248.25	16.55	172.79	13	166	4	-
2.								5	92.32	98.89	19.77	443.81	5	53	37	8
3.								3	11.52	248.46	82.82	216.70	2	1	1	-
4.								4	10.18	303.89	75.79	221.18	2	1	-	-
1.		3,823,742	670	5,707	300,000	167	43	15	23.87	206.65	13.77	172.11	15	272	6	-
2.								5	234.57	44.19	11.04	450.66	4	59	52	42
3.								3	13.78	154.12	77.06	218.03	2	2	-	-
4.								4	10.96	192.03	64.01	228.19	2	4	-	-
1.		3,981,242	700	5,687	300,000	166	42	15	79.93	87.74	5.85	171.11	25	479	212	19
2.								3	3771.13	0	0	457.78	29	ALL OVER 600H		
3.								1	69.60	49.86	49.86	203.17	2	9	7	1
4.								2	56.04	90.91	45.45	215.74	3	17	11	3
1.		4,243,742	750	5,658	300,000	165	42	15	403.28	0	0	170.60	54	ALL OVER 240H		
2.								2	11496.02	0	0	450.16	63	ALL OVER 600H		
4.								1	2312.57	0	0	222.94	13	ALL OVER 600H		
1.		4,495,742	798	5,634	300,000	164	42	15	1204.81	0	0	169.40	130	ALL OVER 600H		

TABLE 6.15 BASRA 1990 MLF B.O. 12H/D

	TYPE	Q.S	N.S.A	A.S.L	B.C	μ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1.	G.C	2,998,445	500	5,997	300,000	175	45	15	10.79	435.77	29.05	179.05	9	94	-	-
2.	GRAIN	1,164,653	59	19,740	400,000	432	100	5	24.72	196.21	39.24	447.09	3	7	5	1
3.	OIL	282,583	19	14,872	400,000	326	65	3	12.74	220.86	73.62	345.79	2	1	-	-
4.	SUGAR	491,506	33	14,849	400,000	326	65	4	11.50	271.28	67.82	341.32	2	1	-	-
1.		3,273,445	550	5,952	300,000	174	44	15	19.72	303.67	20.24	178.03	14	149	9	-
2.								4	95.19	69.71	17.42	442.59	4	32	24	11
3.								2	102.13	137.06	68.53	332.73	3	8	7	4
4.								3	18.93	166.97	55.65	310.67	2	3	2	-
1.		3,548,445	600	5,914	300,000	173	44	15	21.17	236.87	15.79	177.38	12	188	8	-
2.								3	375.20	0	0	467.50	18	ALL OVER 600H		
3.								1	359.05	28.99	28.99	356.10	7	16	15	14
4.								2	62.59	88.72	44.36	356.56	3	9	7	3
1.		3,823,445	650	5,882	300,000	172	44	15	31.78	173.17	11.54	175.12	13	292	20	-
1.		3,960,945	675	5,868	300,000	171	44	15	60.83	91.10	6.07	176.46	20	441	116	4
1.		4,098,445	700	5,855	300,000	171	44	15	151.42	47.78	3.18	176.53	47	668	362	194
1.		4,373,445	750	5,831	300,000	170	43	15	730.30	0	0	175.07	78	ALL OVER 540H		
1.		4,499,945	773	5,821	300,000	170	43	15	1259.22	0	0	175.68	130	ALL OVER 600H		

TABLE 6.16 BASRA 1995 MLF B.O 12H/D

	TYPE	Q.S .	N.S.A	A.S.L	B.C	μ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1.	G.C	3,220,356	500	6,440	300,000	187	48	15	12.76	409.05	27.27	191.90	10	75	1	-
2.	GRAIN	437,921	22	19,905	400,000	436	100	3	11.48	209.14	69.71	464.75	2	1	1	-
3.	OIL	392,647	20	19,632	400,000	430	86	3	15.27	190.11	63.37	440.97	2	1	1	-
4.	SUGAR	580,925	30	19,364	400,000	424	85	4	12.04	250.69	62.67	432.06	2	2	2	-
1.		3,340,356	520	6,424	300,000	187	48	15	17.50	358.01	23.86	192.02	10	116	4	-
3.								2	111.29	90.15	45.08	456.17	4	7	5	3
4.								3	20.04	154.54	51.51	415.44	2	2	1	-
1.		3,580,356	560	6,393	300,000	187	48	15	25.24	292.20	12.48	192.68	14	190	22	-
3.								1	2998.87	0	0	409.92	11	ALL OVER 600H		
4.								2	130.74	52.73	26.36	451.04	4	12	7	6
1.		3,700,356	580	6,380	300,000	186	48	15	32.03	220.85	14.72	191.49	15	238	42	1
1.		3,820,356	600	6,376	300,000	186	48	15	36.59	154.83	10.32	192.04	15	263	42	-
1.		4,120,356	650	6,339	300,000	185	47	15	215.29	10.71	0.71	189.00	40	573	363	273
1.		4,420,356	700	6,315	300,000	184	47	15	1169.95	0	0	189.32	121	ALL OVER 600H		

TABLE 6.17 BASRA 2000 MLF B.O. 12H/D

	TYPE	Q.S	N.S.A	A.S.L	B.C	μ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1.	G.C	3,178,810	500	6,357	300,000	186	48	15	15.25	441.22	29.41	188.86	11	93	2	-
2.	GRAIN	1,000,000	50	20,000	400,000	438	100	5	20.25	218.42	43.68	461.37	4	15	8	1
3.	OIL	545,581	28	19,485	400,000	427	85	3	35.75	166.42	55.47	450.76	4	10	7	6
4.	SUGAR	686,630	35	19,618	400,000	430	86	4	19.89	181.16	45.29	452.36	2	6	2	1
1,		347,881	550	6,325	300,000	185	47	15	24.26	283.46	18.89	189.49	13	171	19	-
2.								4	62.37	141.13	35.28	440.18	3	20	12	7
3.								2	137.03	57.32	28.66	454.90	5	21	11	9
4.								3	33.20	107.37	35.79	419.85	2	5	2	2
1.		3,778,810	600	6,298	300,000	184	47	15	33.53	204.03	13.60	189.79	13	246	37	-
2.								3	213.03	40.99	13.66	454.72	8	27	22	13
4.								2	208.85	32.60	16.30	448.23	4	27	22	13
1.		4,078,810	650	6,275	300,000	183	47	15	180.39	33.50	2.22	188.08	36	566	395	259
1.		4,378,810	700	6,255	300,000	183	47	15	884.19	0	0	188.64	90	ALL OVER 600H		

TABLE 6.18 UM QASR PORT 1985 MLF B.O 12H/D (BASRA G.C SHIPS 670, 871 - 670 = 201)

	TYPE	Q.S	N.S.A	A.S.L	B.C	μ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L.	>24H	>120H	>240H
1.	G.C	1,054,482	201	5,246	300,000	153	35	4	177.83	31.54	7.88	152.91	15	184	149	67
2.	CONT.	1,522,644	597	2,550	500,000	45	7	3	1297.99	0	0	50.30	109	ALL OVER 600H		
								5	26.70	127.27	25.45	153.16	6	68	9	-
								4	24.56	63.83	15.95	49.89	9	264	-	-
								6	12.27	227.76	37.96	153.01	5	29	-	-
								5	11.01	160.95	32.19	50.06	7	70	-	-
								7	7.55	330.08	47.15	153.04	4	12	-	-
								6	6.97	266.11	44.35	50.12	6	8	-	-

TABLE 6.19 UM QASR PORT 1985 MLF B.O 12H/D (BASRA G.C SHIPS 650, 871 - 650 = 221)

1.	G.C	1,159,482	221	5,246	300,000	153	35	4	836.27	0	0	159.40	45	ALL OVER 260H		
								5	120.07	55.58	11.11	159.32	16	127	64	49
								6	51.55	143.13	23.85	159.71	12	81	41	4
								7	21.64	240.97	34.42	159.65	7	50	6	-
								8	9.77	336.20	48.02	159.63	5	18	-	-

TABLE 6.20 UM QASR PORT 1985 MLF B.O 12H/D (BASRA G.C SHIPS 700, 871 - 700 = 171)

	TYPE	Q.S	N.S.A	A.S.L	B.C	μ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1.	G.C	896,982	171	5,245	300,000	153	35	4	65.47	74.83	18.70	159.01	7	97	42	2
								5	17.90	172.83	34.56	159.52	3	40	1	-
								6	7.97	277.58	46.26	159.57	3	10	-	-
								7	5.71	382.51	54.64	159.34	3	2	-	-

TABLE 6.21 UM QASR PORT 1990 MLF B.O 12H/D (BASRA G.C. SHIPS 600, 1182 - 650 = 532)

1.	G.C	2,922,848	532	5,494	300,000	160	36	10	114.32	54.50	5.45	162.63	23	385	235	56
2.	CONT.	2,831,531	191	3,104	500,000	54	9	6	385.94	0	0	60.21	59	ALL OVER 600H		
								11	28.41	156.54	14.23	162.50	11	191	11	-
								7	21.61	90.35	12.90	60.07	11	317	-	-
								12	15.78	255.28	21.27	162.70	10	95	-	-
								8	9.83	194.30	24.28	59.92	7	82	-	-
								13	11.20	355.15	27.31	162.75	9	60	-	-
								9	7.23	296.87	32.98	60.02	7	26	-	-
								14	8.70	455.50	32.53	162.69	8	36	-	-
								10	6.06	399.14	39.91	59.99	7	6	-	-

TABLE 6.22 UM QASR PORT 1990 MLF B.O 12H/D (BASRA G.C SHIPS 600, 1182-600 = 582)

TYPE	Q.S	N.S.A	A.S.L	B.C	μ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1. G.C	3,197,848	582	5,495	300,000	160	36	10	1327.89	0	0	165.63	107	ALL OVER 600H		
							11	263.06	7.63	0.69	165.90	35.	571	511	336
							12	55.74	114.61	9.55	165.98	16	341	102	-
							13	29.50	216.05	16.61	165.96	15	219	-	-
							14	16.96	309.50	22.10	165.99	14	129	-	-

TABLE 6.23 UM QASR PORT 1990 MLF B.O 12H/D (BASRA G.C SHIPS 700, 1182-700 = 482)

1. G.C	2,674,848	482	5,495	300,000	160	36	10	62.25	103.00	10.30	164.60	13	295	94	-
							11	19.10	208.48	18.94	164.62	9	144	-	-
							12	9.81	303.98	25.33	164.98	7	50	-	-

TABLE 6.24 UM QASR PORT 1995 MLF B.O 12H/D (BASRA G.C SHIPS 600, 1815-600 = 1215)

	TYPE	Q.S	N.S.A	A.S.L	B.C	μ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1.	G.C	7,290,015	1,215	6,000	300,000	175	40	24	236.07	0	0	180.87	54	1210	1070	646
2.	CONT.	4,653,358	1,508	3,086	500,000	54	9	10	366.20	0	0	59.37	85	1540	1540	1455
								25	62.69	71.63	2.86	180.70	28	798	208	-
								11	29.64	86.95	7.90	59.32	25	782	-	-
								26	38.20	161.49	6.21	180.85	26	588	57	-
								12	13.49	190.49	15.87	59.20	16	284	-	-
								27	25.41	271.11	10.04	180.93	23	431	13	-
								13	9.13	292.24	22.48	59.15	12	124	-	-
								28	17.74	371.36	13.26	180.98	19	278	2	-
								14	6.97	392.23	28.01	59.15	10	28	-	-
								29	13.57	461.16	15.90	180.82	16	202	-	-
								15	6.08	490.13	32.67	59.24	8	24	-	-
								30	10.62	564.59	18.81	180.77	13	148	-	-
								16	5.63	590.73	36.92	59.25	8	-	-	-

TABLE 6.25- UM QASR PORT 1995 MLF B.O 12H/D (BASRA G.C SHIPS 560, 1815-560 = 1255)

TYPE	Q.S	N.S.A	A.S.L	B.C	μ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1. G.C	7,530,015	1,255	6,000	300,000	·175	40	24	367.50	0	0	180.03	78	1210	1210	1096
							25	70.09	66.43	2.65	179.84	31	929	225	-
							26	39,87	164.72	6.33	179.86	23	667	45	-
							27	23.65	264.43	9,79	179.74	21	409	14	-
							28	16.83	376.52	13.44	179.79	19	266	7	-
							29	13.32	469.43	16.18	179.78	18	193	2	-
							30	11.24	569.77	18.99	179.81	15	154	-	-

TABLE 6.26 UM QASR PORT 1995 MLF B.O 12H/D (BASRA GC. SHIPS 650, 1815 - 650 = 1165)

TYPE	Q.S	Ṅ.S.A	A.S.L	B.C	µ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1. G.C	6,990,015	1,165	6,000	300,000	175	40	24	45.75	129.90	5.41	179.95	25	630	91	-
							25	26.13	242.88	9.71	179.91	18	399	5	-
							26	17.51	341.17	13.12	179.91	15	286	-	-
							27	12.07	441.19	16.34	179.90	13	181	-	-
							28	9.06	550.46	19.65	179.96	11	100	-	-
							29	7.37	664.55	22.91	179.83	9	58	-	-
							30	6.42	772.29	25.74	179.84	8	32	-	-

TABLE 6.27 UM QASR PORT 2000 MLF B.0.12H/D (BASRA G.C SHIPS 600, 3026-600 = 2426)

	TYPE	Q.S	N.S.A	A.S.L	B.C	μ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1.	G.C	14,552,784	2,426	5,999	300,000	175	40	49	358.79	0	0	180.40	139	ALL OVER 200H		
2.	CONT.	7,690,757	2,504	3,071	500,000	54	9	16	640.50	0	0	59.18	212	ALL OVER 500H		
3.	AUT.C	149,781	100	1,499	300,000	44	7	1	26.40	45.91	45.91	48.20	3	39	1	-
								50	133.80	0.	0	180.45	70	2360	1532	-
								17	43.57	52.75	3.10	59.29	41	1646	36	-
								2	7.56	145.10	72.55	49.00	3	3	-	-
								51	45.12	11.05	2.17	180.34	49	1491	89	-
								18	19.10	155.74	8.65	59.25	26	730	-	-
								52	27.06	217.91	4.19	180.24	39	1007	4	-
								19	12.18	255.54	13.44	59.29	22	349	-	-
								53	19.31	317.49	5.99	180.23	31	741	-	-
								20	9.44	354.55	17.72	59.34	20	175	-	-
								54	14.98	416.45	7.71	180.36	29	570	-	-
								21	8.00	452.68	21.55	59.42	18	107	-	-
								55	12.46	515.62	9.37	180.45	24	421	-	-
								22	7.04	553.75	25.17	59.39	17	62	-	-
								56	10.46	618.12	11.03	180.44	18	317	-	-
								23	6.44	654.89	28.47	59.38	16	35	-	-
								57	9.26	714.53	12.53	180.52	17	220	-	-
								24	6.11	755.52	31.48	59.35	15	21	-	-

TABLE 6.28 UM QASR PORT 2000 MLF B.O 12H/D (BASRA GC SHIPS 550, 3026-550 = 2476)

	TYPE	Q.S	N.S.A	A.S.L	B.C	μ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1.	G.C	14,852,784	2,476	5,999	300,000	175	40	50	254.19	0	0	180.02	98	ALL OVER 130H		
								51	57.83	69.76	1.36	180.08	50	1981	175	-
								52	23.76	243:89	4.69	179.78	28	963	-	-
								53	18:30	338:78	6.39	179.90	24	713	-	-
								54	14.56	436:58	8.08	179.90	23	512	-	-
								55	11.82	539:90	9.81	179.79	22	346	-	-
								56	10:08	640:06	11.42	179.86	21	257	-	-
								57	8.88	738:61	12.95	179.89	19	191	-	-

TABLE 6.29 UM QASR PORT 2000 MLF B.O 12H/D (BASRA G.C SHIPS 650, 3026-650 = 2376)

	TYPE	Q.S	N.S.A	A.S.L	B.C.	μ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1.	G.C	14,252,784	2,376	5,999	300,000	175	40	49	62.49	74.28	1.51	180.16	48	1877	269	-
1.								50	23.87	245.47	4.90	180.11	29	857	-	-
1.								51	18.72	342.68	6.71	180.15	27	657	-	-
1.								52	14.94	441.36	8.48	180.07	25	512	-	-
1.								53	12.30	538.10	10.15	180.00	23	353	-	-
1.								54	10.42	634.02	11.74	180.00	22	255	-	-
1.								55	9.20	732.95	13.32	179.98	21	198	-	-
1.								56	8.29	832.84	14.87	179.91	20	123	-	-
1.								57	7.59	931.07	16.33	179.92	19	80	-	-

TABLE 6.30 KHOR AL ZUBAIR 1985 MLF B.O 12H/D

	TYPE	Q.S	N.S.A	A.S.L	B.C	μ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1.	FERT.	438,070	44	9,956	550,000	159	40	1	745.26	0.90	0.90	160.62	8	43	41	40
2.	SULPHUR	1,023,866	69	14,838	550,000	236	38	2	1902.34	0	0	240.13	21	ALL OVER 600H		
3.	UREA	750,000	75	10,000	550,000	159	35	2	162.27	26.79	13.40	170.09	8	49	40	26
4.	PHOSP.	250,000	25	10,000	550,000	159	26	1	51.01	62.74	62.74	165.80	2	8	3	-
1.								2	12.17	114.45	57.22	160.93	2	5	-	-
2.								3	47.22	75.19	25.06	239.76	3	29	8	-
3.								3	28.05	113.64	37.88	169.98	4	22	4	-
4.								2	6.33	163.29	81.64	167.57	2	-	-	-

TABLE 6.31 KHOR AL ZUBAIR 1990-2000 MLF B.O 12H/D

	TYPE	Q.S	N.S.A	A.S.L	B.C	μ	σ	N.B.	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1.	FERT.	1,000,000	50	20,000	550,000	319	81	2	5518.31	0	0	335.45	41	ALL OVER 600H		
2.	SULPHUR	1,500,000	75	20,000	550,000	319	52	3	171.02	45.74	15.24	331.09	6	43	27	18
3.	UREA	1,000,000	50	20,000	550,000	319	70	2	1303.34	0	0	309.15	12	45	44	43
4.	PHOSP.	1,500,000	75	20,000	550,000	319	50	3	450.11	16.52	5.50	326.87	9	66	64	60
1.								3	434.14	6.53	2.17	335.35	9	57	54	47
2.								4	40.09	145.61	36.40	330.78	4	20	8	1
3.								3	38.13	111.78	37.26	308.88	3	13	7	-
4.								4	75.67	106.76	26.69	326.04	5	34	24	8
1.								4	43.79	104.05	26.01	335.73	4	23	9	1
2.								5	10.80	249.85	49.97	331.35	2	6	-	-
3.								4	11.11	189.71	47.42	308.75	2	3	2	-
4.								5	32.37	215.10	43.02	325.60	4	17	9	-

TABLE 6.32 UM QASR PORT 1985 OPTIMISTIC FORECASTS B.O 24H/D (BASRA G.C SHIPS = 670, 1018 - 670 = 348)

	TYPE	Q.S	N.S.A	A.S.L	B.C	μ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1.	G.C.	1,827,001	348	5,250		77	17	3	1203.07	0	0	78.02	59	ALL OVER 600H		
2.	CONT.	1,802,267	709	2,542	1,000,000	22	4	2	77.69	6.02	3.01	23.91	20	592	143	1
								4	18.80	95.11	23.77	77.90	8	85	5	-
								3	6.24	106.09	35.36	24.07	6	35	-	-
								5	6.12	192.99	38.59	77.91	5	27	-	-
								4	2.82	206.97	51.74	24.06	5	-	-	-
								6	2.87	292.85	48.80	77.84	4	5	-	-
								5	2.04	302.53	60.50	24.02	4	-	-	-

TABLE 6.33 UM QASR PORT 1990 OPTIMISTIC FORECASTS B.O 24H/D (BASRA G.C SHIPS 650, 1573 - 650 = 932

1.	G.C	5,076,417	932	5,447	600,000	80	18	9	69.74	34.43	3.82	81.40	24	649	224	-
2.	CONT.	3,639,356	1182	3,079	1,000,000	27	5	4	37.11	26.71	6.67	28.86	16	688	-	-
								10	25.53	135.91	13.59	81.32	18	324	13	-
								5	6.19	126.71	25.34	28.87	7	36	-	-
								11	10.98	229.46	20.86	81.45	13	147	-	-
								6	2.93	227.48	37.91	28.82	6	-	-	-
								12	6.11	323.88	26.99	81.45	11	82	-	-
								7	2.09	330.04	47.18	28.86	5	-	-	-
								13	3.90	422.59	32.50	81.50	8	40	-	-
								8	1.83	429.03	53.62	28.88	5	-	-	-

TABLE 6.34 UM QASR PORT 1995 OPTIMISTIC FORECASTS B.O 24 H/D (BASRA G.C SHIPS 560, 2759 - 560 = 2199)

	TYPE	Q.S	N.S.A	A.S.L	B.C	μ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1.	G.C	13,194,872	2,199	6,000	600,000	88	20	22	185.62	0.38	0.017	90.11	118	2074	1255	765
2.	CONT.	6,778,299	2,216	3,059	1,000,000	27	5	7	549.37	0	0	28.61	239	ALL OVER 200H		
								23	67.72	45.58	1.98	90.12	52	1556	41	-
								8	21.25	44.90	5.61	28.65	24	943	-	-
								24	22.01	123.39	5.14	90.08	25	894	-	-
								9	6.84	143.76	15.97	28.63	13	111	-	-
								25	12.36	223.68	8.94	90.08	23	421	-	-
								10	3.86	243.07	24.30	28.65	12	8	-	-
								26	7.66	324.48	12.44	90.08	22	156	-	-
								11	2.57	345.42	31.42	28.62	9	2	-	-

TABLE 6.35 UM QASR PORT 2000 OPTIMISTIC FORECASTS B.O 24H/D (BASRA G.C SHIPS 550, 5251 - 550 = 4701)

1.	G.C	28,201,479	4,701	5,999	600,000	88	20	48	315.61	0	0	90.11	263	ALL OVER 192H		
2.	CONT.	12,624,861	4,149	3,043	1,000,000	27	5	13	662.25	0	0	28.55	385	ALL OVER 468H		
								49	145.53	0	0	90.11	131	ALL OVER 48H		
								14	46.05	30.79	2.19	28.55	67	2654	85	-
								50	47.97	67.10	1.34	90.17	69	3164	-	-
								15	8.62	146.60	9.77	28.53	26	325	-	-
								51	19.49	160.22	3.14	90.10	41	1681	-	-
								16	4.95	246.17	15.38	28.55	18	32	-	-
								52	11.16	251.19	4.83	90.09	31	610	-	-
								17	3.33	345.70	20.33	28.56	15	-	-	-
								53	8.06	351.25	6.62	90.10	28	411	-	-
								18	2.53	447.02	24.83	28.54	11	-	-	-

TABLE 6.36 UM QASR PORT 1985 PESSIMISTIC FORECASTS B.O 12H/D (BASRA G.C SHIPS 670, 743 - 670 = 73)

	TYPE	Q.S	N.S.A	A.S.L	B.C	μ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1.	G.C	379,600	73	5,200	300,000	152	35	2	81.47	44.83	22.41	158.57	5	54	26	6
2.	CONT.	1,292,884	505	2.560	500,000	45	7	3	63.42	21.46	7.15	49.46	14	344	67	-
								3	13.49	148.64	49.54	159.09	3	10	3	-
								4	11.58	119.99	29.99	49.37	5	69	-	-
								4	7.81	226.20	56.55	159.39	2	3	1	-
								5	7.20	217.44	43.48	49.43	5	16	-	-
								5	5.48	311.75	62.35	159.21	2	1	-	-
								6	5.98	324.39	54.06	49.36	5	2	-	-

TABLE 6.37 UM QASR PORT 1990 PESSMISTIC FORECASTS B.O 12H/D (BASRA G.C SHIPS 650, 883 - 650 = 233)

1.	G.C	1,279,093	233	5,490	300,000	160	36	5	58.05	77.28	15.45	161.32	12	104	35	14
2.	CONT.	2,214,949	707	3,133	500,000	55	9	5	100.04	13.52	2.70	60.68	26	583	233	53
								6	25.34	180.96	30.16	160.99	10	55	13	-
								6	22.39	97.18	16.19	60.96	11	288	-	-
								7	13.30	275.25	39.32	161.15	9	22	5	-
								7	10.43	195.15	27.87	60.86	7	88	-	-
								8	9.35	368.71	46.08	160.99	5	16	-	-
								8	7.48	296.78	37.09	60.86	6	30	-	-
								9	7.11	459.81	51.09	161.04	3	7	-	-
								9	6.12	400.49	44.49	60.83	5	6	-	-

TABLE 6.38 UM QASR PORT 1995 PESSIMISTIC FORECASTS B.O 12H/D (BASRA G.C SHIPS 560, 1186 - 560 = 626)

	TYPE	Q.S	N.S.A	A.S.L	B.C	μ	σ	N.B	A.W.T	% I.T.	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1.	G.C	3,752,023	626	5,994	300,000	175	40	13	85.30	53.70	4.13	175.89	22	488	180	20
2.	CONT.	3,236,207	1,036	3,124	500,000	55	9	7	306.53	0	0	61.07	53	ALL OVER 120H		
								14	41.52	148.21	10.58	176.05	16	282	75	-
								8	23.69	84.19	10.52	61.05	14	419	-	-
								15	26.58	238.48	15.89	176.10	14	194	18	-
								9	11.41	182.64	20.29	61.15	8	137	-	-
								16	17.37	329.29	20.58	176.07	13	130	-	-
								10	7.92	282.36	28.23	61.12	7	48	-	-
								17	12.42	424.20	24.95	176.07	12	90	-	-
								11	6.49	381.37	34.67	61.09	7	15	-	-
								18	9.39	527.77	29.32	176.07	11	54	-	-
								12	5.74	479.20	39.93	61.17	7	2	-	-

TABLE 6.39 UM QASR PORT 2000 PESSIMISTIC FORECASTS B.O 12H/D (BASRA C.G SHIPS 550, 1717 - 550 = 1167)

	TYPE	Q.S	N.S.A	A.S.L	B.C	μ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1.	G.C	6,998,976	1,167	5,997	300,000	175	40	24	62.27	66.90	2.78	180.16	25	888	167	-
2.	CONT.	3,747,114	1,190	3,149	500,000	55	9	8	358.80	0	0	60.40	65	ALL OVER 192H		
								25	31.98	162.39	6.49	180.29	21	542	14	-
								9	24.32	88.30	9.81	60.36	16	512	-	-
								26	20.95	256.81	9.87	180.26	14	382	-	-
								10	11.66	186.92	18.69	60.30	13	167	-	-
								27	14.13	351.17	13.00	180.18	13	230	-	-
								11	8.00	286.15	26.01	60.21	10	66	-	-
								28	10.78	450.90	16.10	180.36	12	141	-	-
								12	6.49	384.04	32.00	60.17	9	28	-	-
								29	8.67	551.34	19.01	180.24	11	84	-	-
								13	5.97	476.47	36.65	60.17	8	15	-	-
								30	7.32	649.94	21.66	180.24	10	46	-	-
								14	5.73	568.89	40.63	60.15	8	7	-	-

CHAPTER 7

ANALYSIS OF SIMULATION RESULTS

7.1 Introduction

In this chapter the simulation results shown in Tables 6.11 to 6.39 of Chapter 6 will be analysed to show how the average waiting times, berth idle times and queue lengths vary as the number of ships arriving at the port increases (for the general cargo traffic at Basra port, since there is no room for expanding the 15 berths); and as the number of berths (that is, the berthing capacity) increases for the rest of the cargo types in all three ports.

The average waiting times will be analysed in Section 7.2, berth idle time will be analysed in Section 7.3 and the queue lengths will be analysed in Section 7.4.

Only the results of the most likely forecasts where the berths are operational for two shifts will be dealt with in this chapter since the same relationships hold and similar results will be obtained from the other forecasts where they will be analysed in Chapter 8.

7.2 Average Waiting Times

As ships arrive at the port, they are admitted to the vacant berths to receive service and then depart to the open sea. Depending on the berthing capacity available, the number of ships arriving in a particular time period and the time taken to service the ship congestion might occur, that is, different ships may have to wait for different time periods before they can receive service, simply because the available berths are occupied by the previous ships when new ones arrive. The longer the berths are occupied, the longer the ships have to wait before receiving service, and vice-versa, the shorter the berths are occupied, the shorter the ships have to wait.

In the case of the general cargo traffic (Basra port) the berthing capacity is made up of the 15 available general cargo berths which cannot be increased further to cater for an increasing amount of traffic. To show how the average waiting time per ship varies with the number of ships arriving per year, different simulations were carried out for an increasing number of ships (an increasing amount of cargo) for the periods 1985, 1990, 1995 and 2000, as can be seen in Tables 6.14 to 6.17 of Chapter 6. It can be seen from those tables that the higher the number arriving requiring service, the higher the average waiting time gets (that is, the higher the congestion becomes) eventually resulting in very high average waiting times per ship (see for example, Tables 6.14, 6.15, 6.16 and 6.17, when 700 arrivals or more are simulated).

To illustrate this graphically, the above tables were used and the average waiting time per ship was plotted against the number of ships arriving for each time period and the results are shown in Figure 7.1. This figure shows that the average waiting time increases at a small rate up to a certain point beyond which it becomes rapid indicating that the berths are becoming congested (that is, the berthing capacity available becomes insufficient to service the ships) eventually leading to chronic congestion. The figure shows that the 15 general cargo berths (Basra port) can accomodate approximately 670 ships in 1985 and 1990 and approximately 600 ships in 1995 and 2000 where the average waiting time might be tolerable (small) and beyond this point the average waiting times go up very rapidly, resulting in very high penalties as will be seen in Chapter 8. The figure also shows that the turning point in the curve in 1985 is farther than 1990, and 1990 is farther than 1995 and 2000, that is the 15 berths can service a higher number of ships in 1985 than in 1990 ... etc. with the same average waiting time. The reason for this is simply that the average ship load (amount of cargo handled) in 1985 is smaller than that for 1990 onwards which takes a smaller time period to service.

The average waiting times were plotted against the number of berths for grain traffic, oil traffic and sugar traffic using the same tables and the results are shown in Figures 7.2, 7.3 and 7.4 respectively. Those figures show that the higher the number of berths (the higher the berthing capacity) the lower the average waiting time per ship and vice-versa, that is, the more berths there are, the smaller is the time ships have to wait for a free berth. It can also be seen from those figures that the average waiting time for the same number of berths is increasing in each time period due to the fact that the amount of cargo handled in each time period is also increasing and so is the average ship load hence requiring a longer time period for service, except for grain traffic where the reverse is true, since the amount of cargo handled is decreasing and the average ship load is almost constant.

From Tables 6.18, 6.21 6.24 and 6.27, the average waiting times were plotted against the number of berths for general cargo and container traffic and the results shown in Figures 7.5 and 7.6 respectively. Finally, for Khor Al Zubair port Tables 6.30 and 6.31 were used to obtain Figures 7.7 to 7.10 for fertiliser, sulphur, urea and phosphate traffic respectively. The results obtained in Figures 7.5 to 7.10 are similar to the ones discussed earlier.

From those figures, decision concerning the number of ships that can be serviced by a constant berthing capacity, or the number of berths that are required to handle a known amount of cargo can be made. Those decisions will not be optimal but approximate, serving as guidelines since optimal decisions have to take into consideration the penalties paid in waiting costs which might be different for each type of ship and its size, which is the topic of Chapter 8. Nevertheless if we look at Figure 7.1 for example, we can see that in the year 1985, the average waiting time changes very slightly when 550 - 650 ships are serviced, indicating that the waiting costs for 550, 600 or 650 ships will be very similar, that is, a decision can be made to service 650 ships instead of 550. It can also be seen that when the number of ships serviced is 700 or more the average waiting time goes up rapidly, indicating that the waiting costs go up at the same rate and sometimes at a higher rate since extra costs (surcharges) are paid in chronic

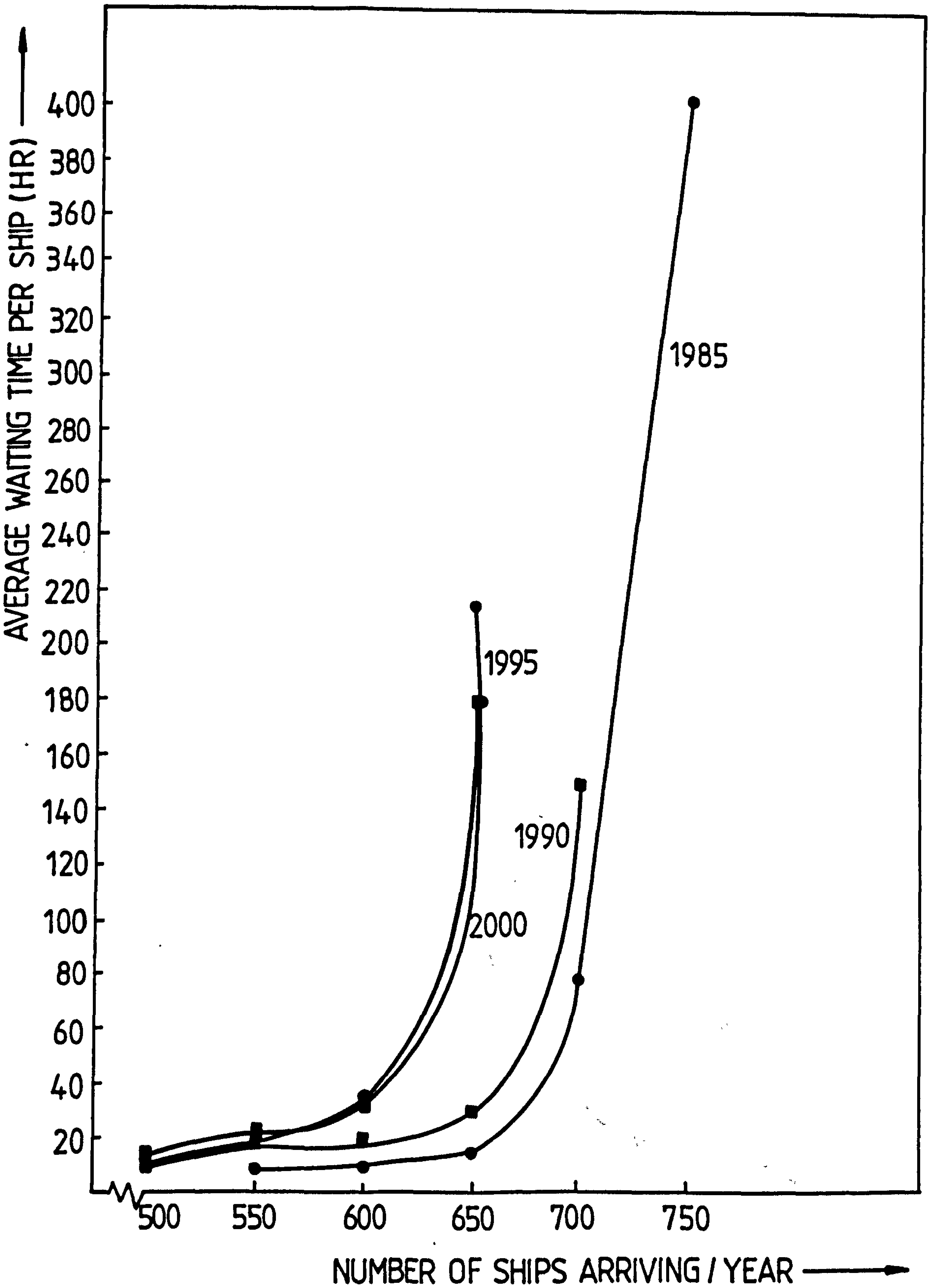


FIGURE 7-1 BASRA PORT, GENERAL CARGO, MOST LIKELY FORECASTS, AV. WT. / SHIP V. NUMBER OF SHIPS ARRIVING PER YEAR, BERTHS OPERATE 12 HOURS

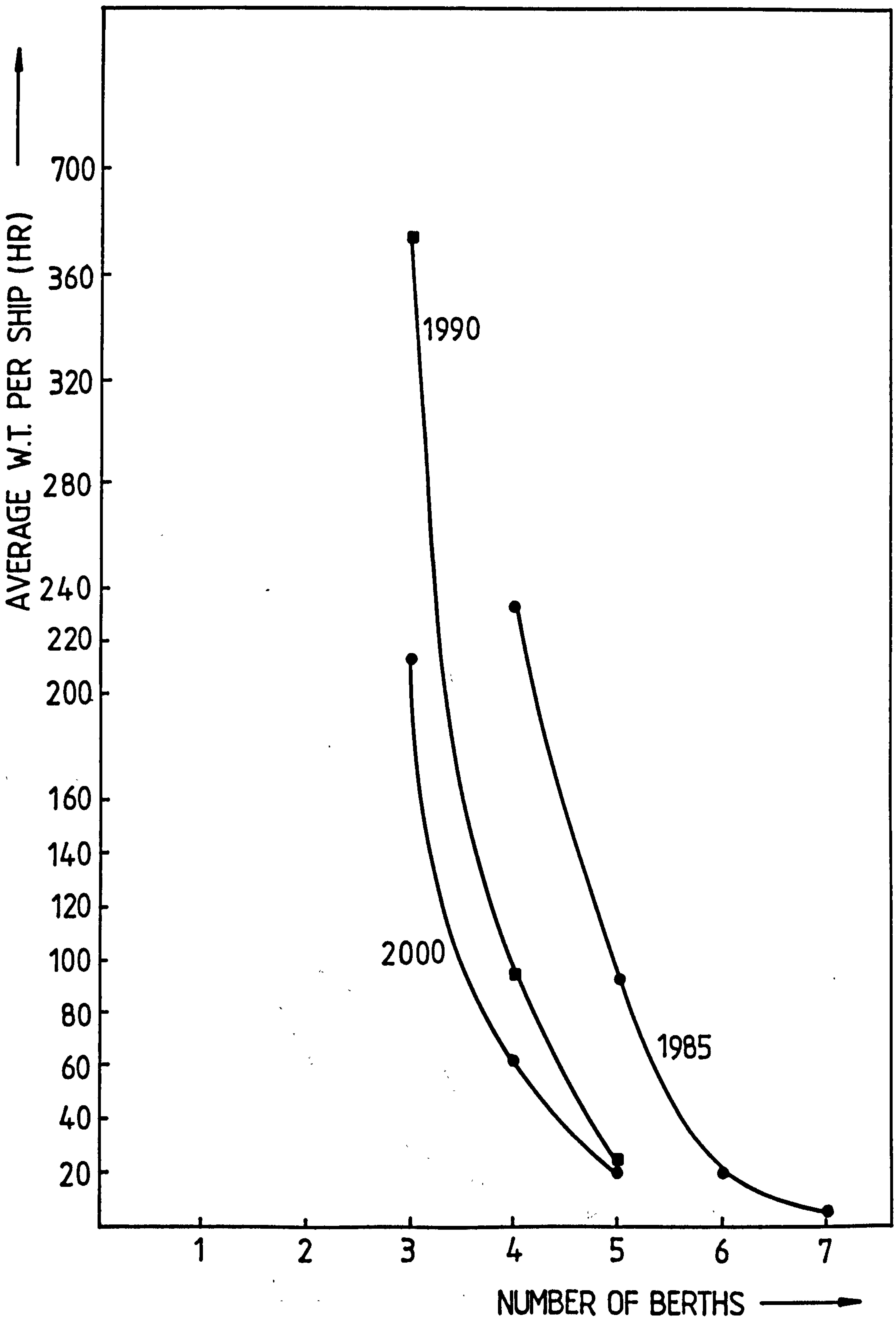


FIGURE 7-2 BASRA PORT, GRAIN TRAFFIC, MOST LIKELY FORECASTS, AV. WT / SHIP V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS

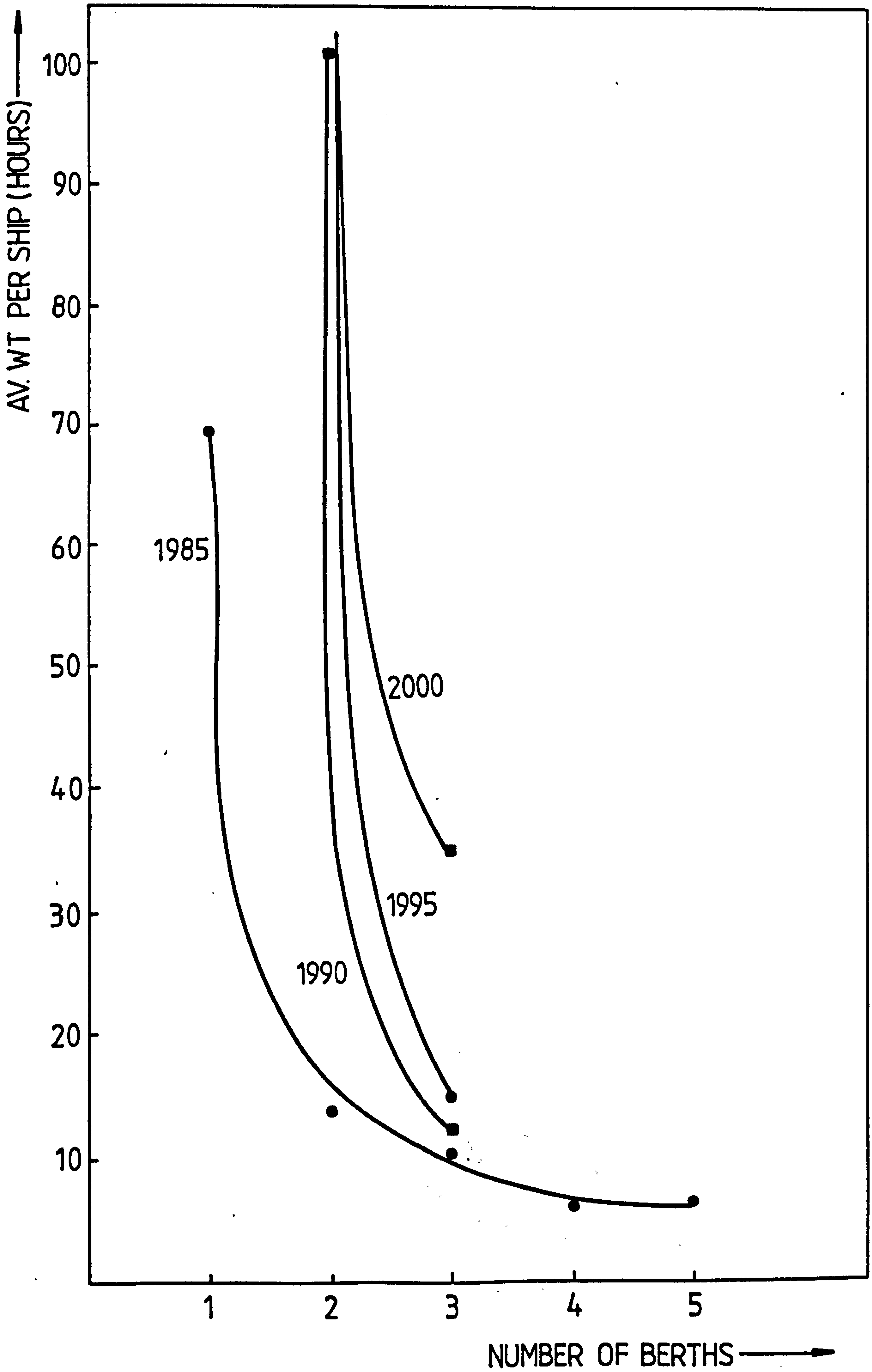


FIGURE 7-3 BASRA PORT, OIL TRAFFIC, MOST LIKELY FORECASTS, AV. WT. PER SHIP V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS

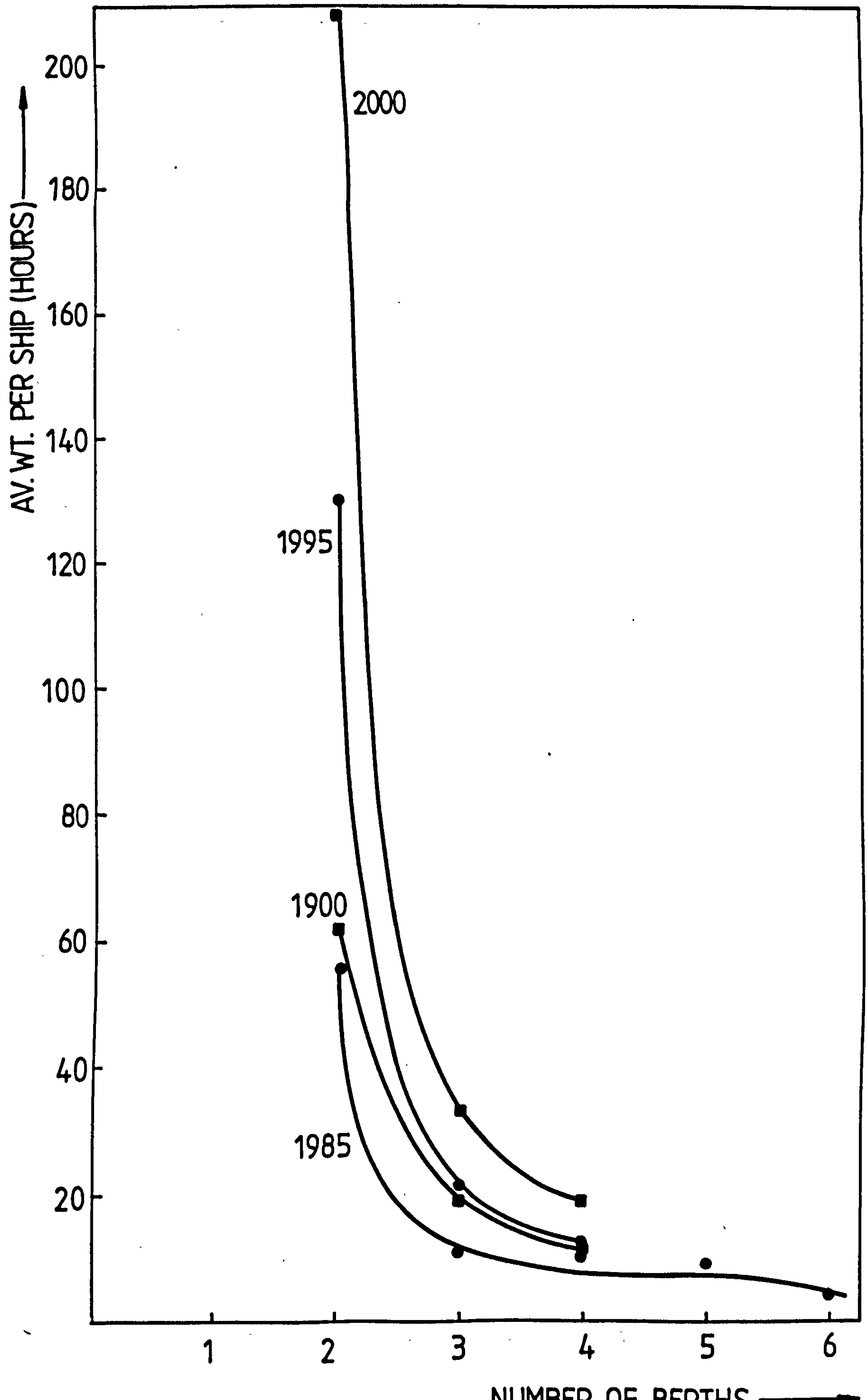


FIGURE 7-4 BASRA PORT, SUGAR TRAFFIC, MOST LIKELY FORECASTS, AV. WT. PER SHIP V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS

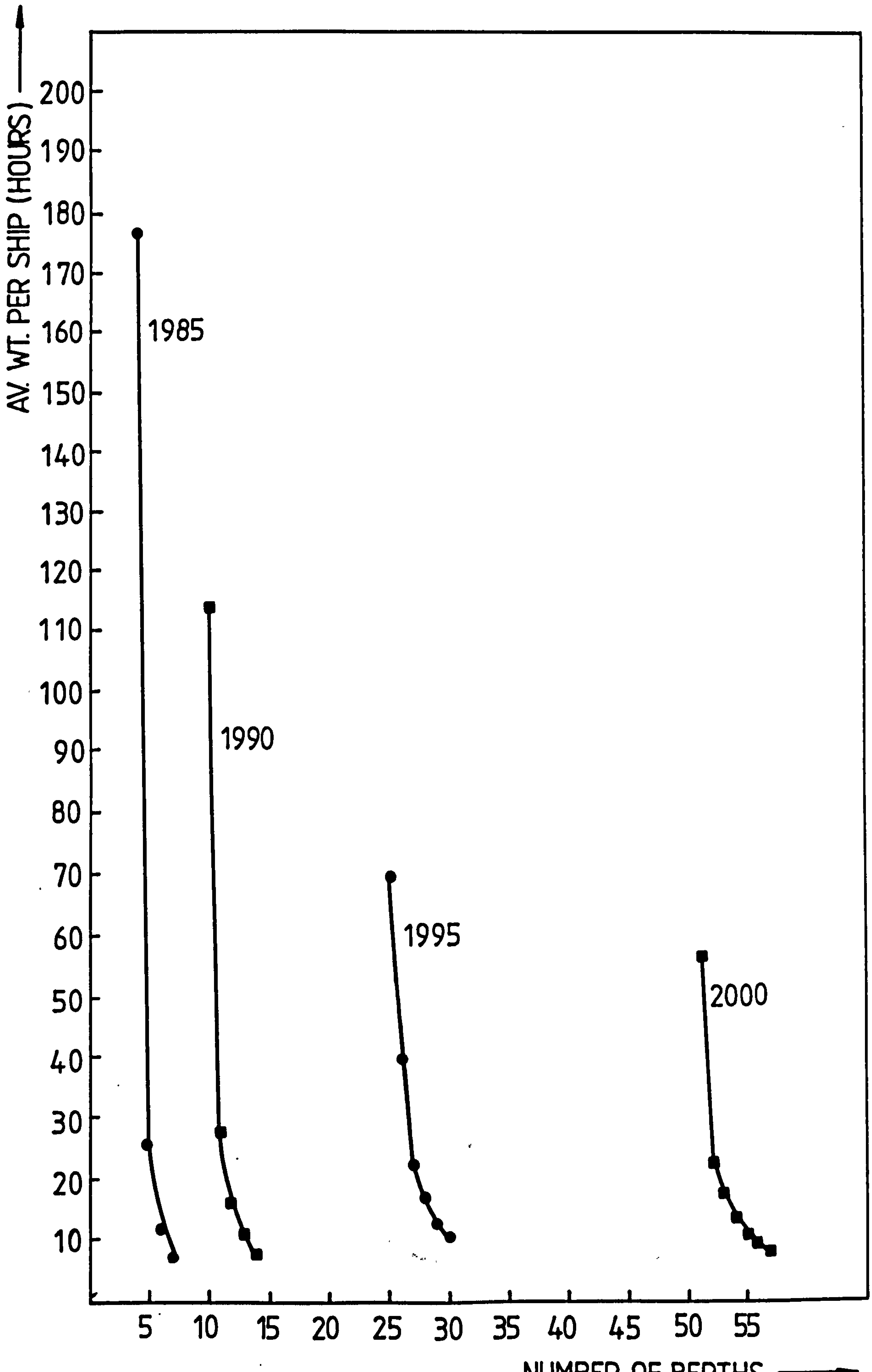


FIGURE 7-5 UM QASR PORT, GENERAL CARGO, MOST LIKELY FORECASTS, AV. WT. PER SHIP V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS

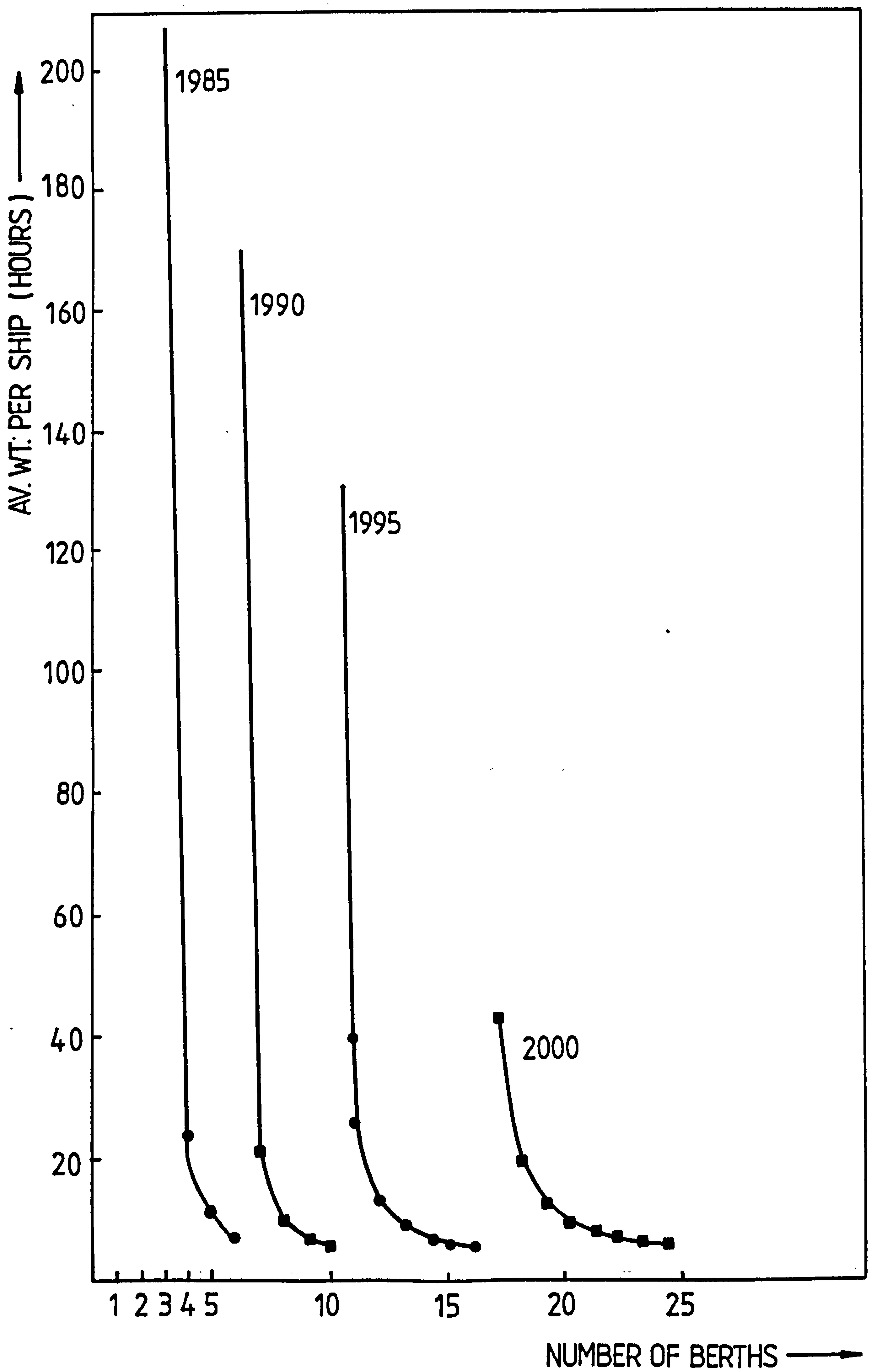


FIGURE 7-6 UM QASR PORT, CONTAINER TRAFFIC, MOST LIKELY FORECASTS, AV. WT. PER SHIP V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS

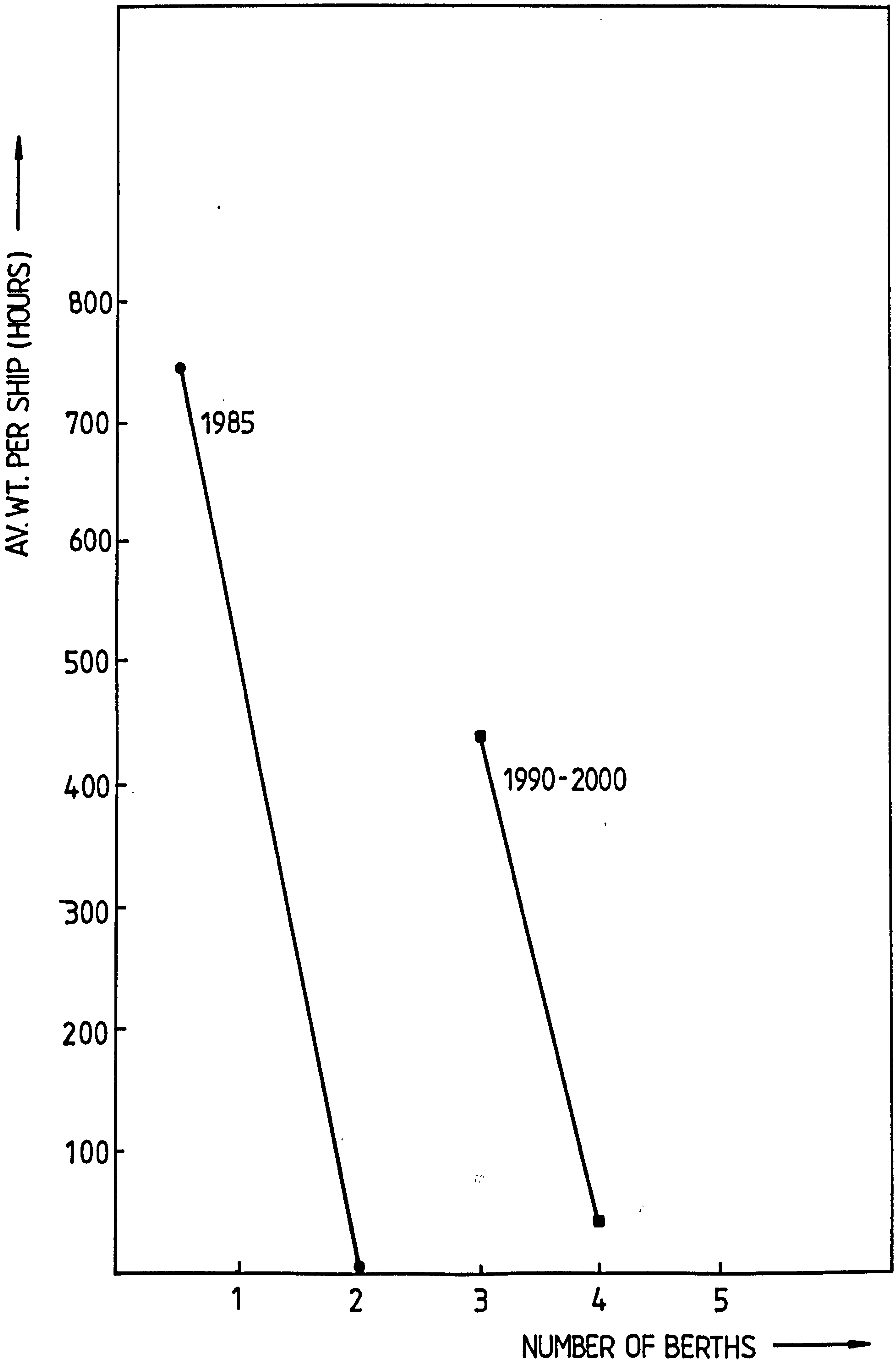


FIGURE 7-7 KHOR AL-ZUBAIR PORT, FERTILISER TRAFFIC, MOST LIKELY FORECASTS, AV. WT. PER SHIP V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS

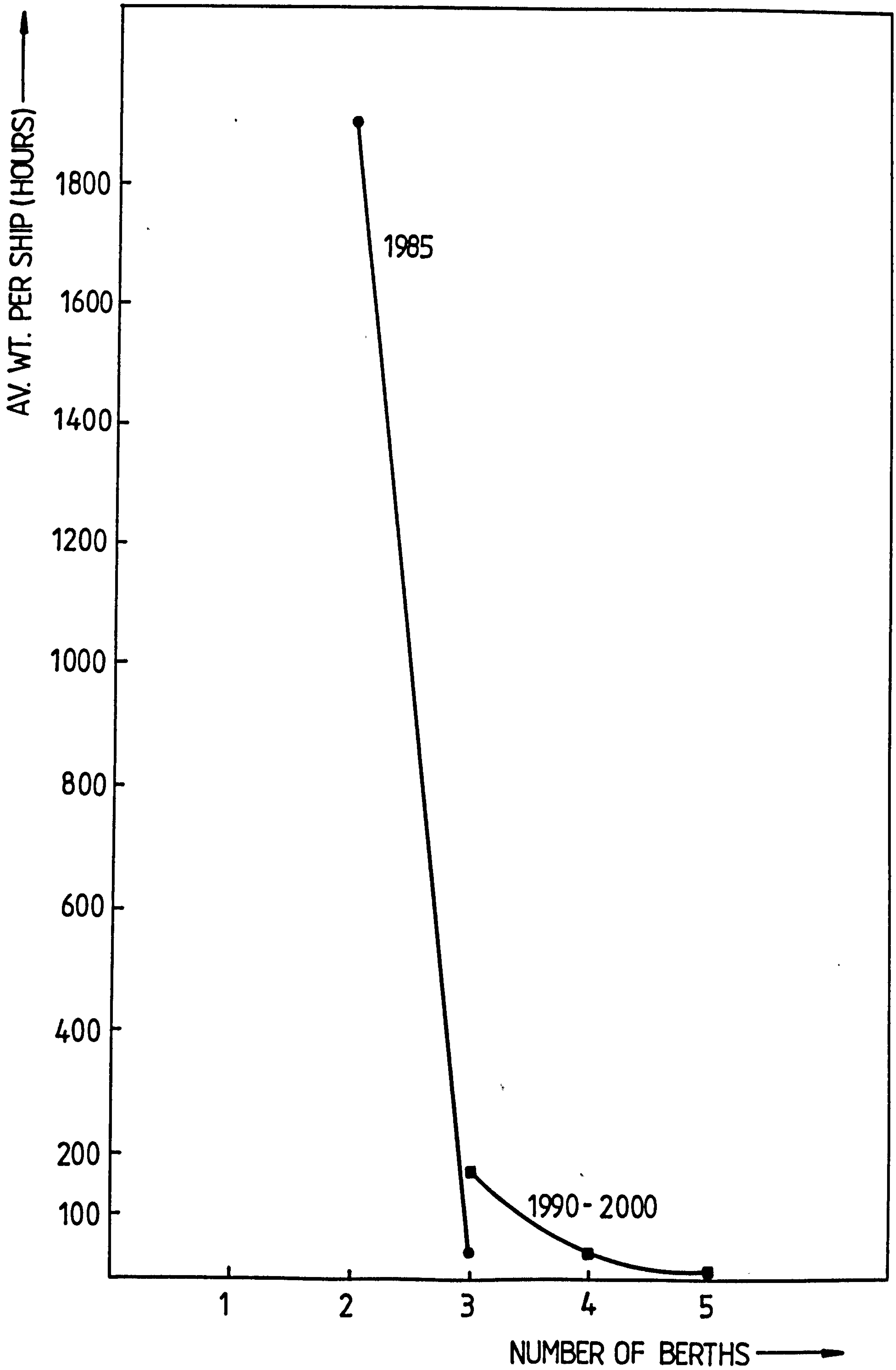


FIGURE 7-8 KHOR AL - ZUBAIR PORT, SULPHUR TRAFFIC, MOST LIKELY FORECASTS, AV. WT. PER SHIP V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS

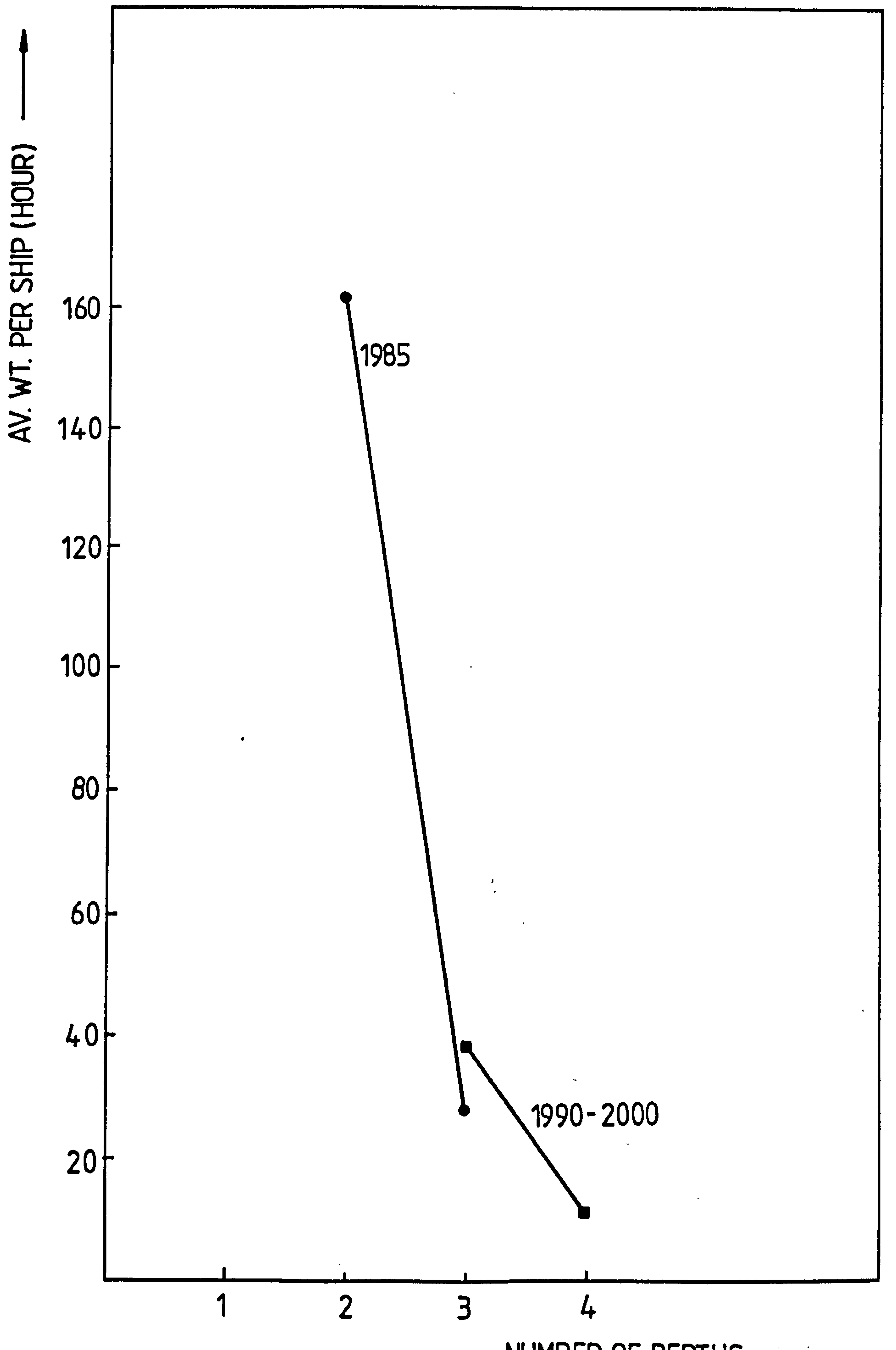


FIGURE 7-9 KHOR AL-ZUBAIR PORT, UREA TRAFFIC, MOST LIKELY FORECASTS, AV. WT. PER SHIP V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS

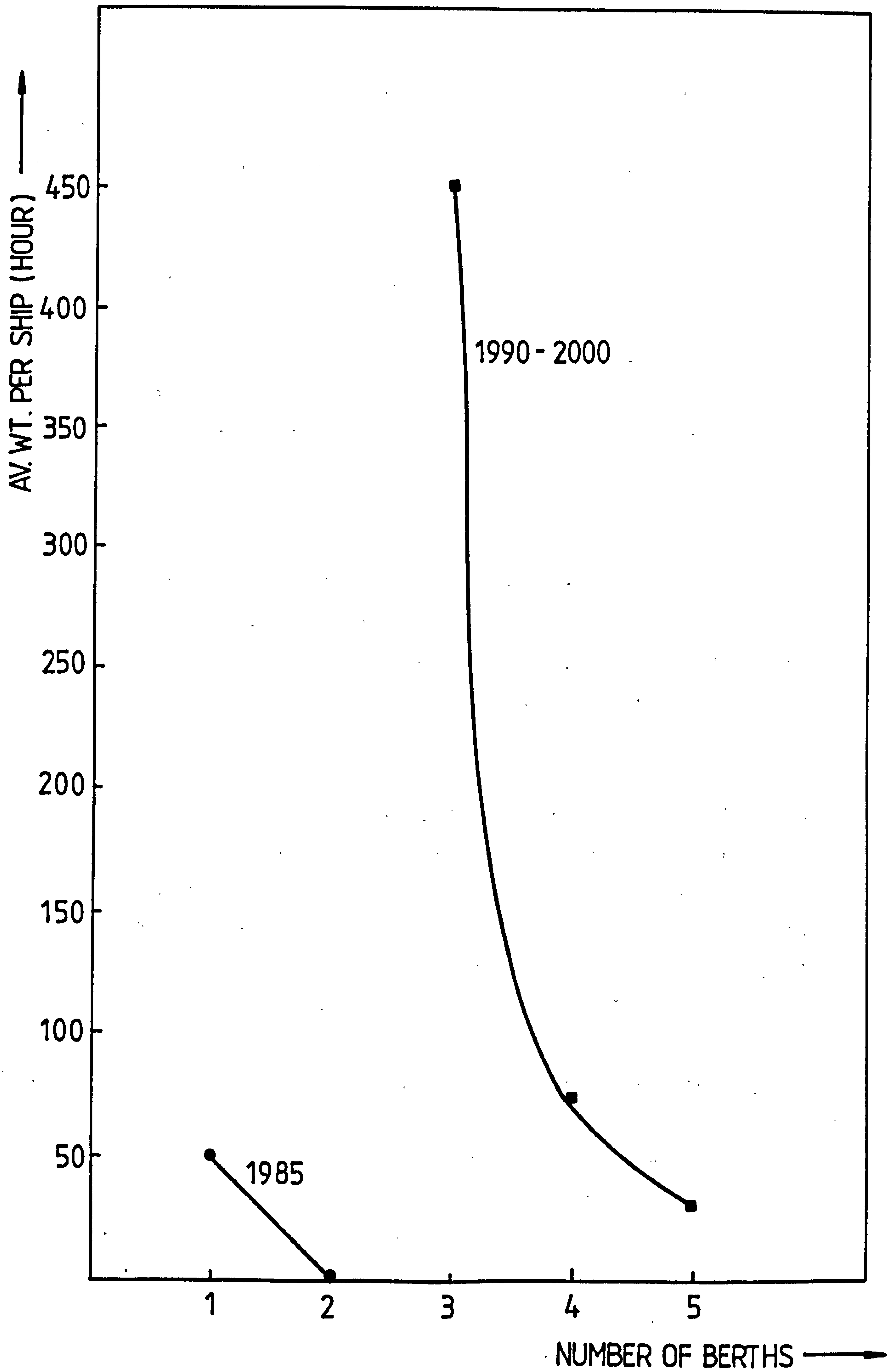


FIGURE 7-10 KHOR AL-ZUBAIR PORT, PHOSPHATE TRAFFIC, MOST LIKELY FORECASTS, AV. WT. PER SHIP V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS

congestion. Therefore from this figure we can conclude that the 15 general cargo berths in Basra port can service between 650 and 700 ships approximately in 1985 without causing chronic congestion, between 550 and 675 ships approximately in 1995 and 2000 without causing chronic congestion. Such information is very useful to port planners without any further analysis.

7.3 Percentage Berth Idle Time

Another statistic which is often useful in port planning is the percentage berth idle time (or percentage berth utilisation, which is, 100 - percentage berth idle time). From this statistic we are able to know how long the berth is kept idle (free) or busy (occupied).

Like the average waiting time, the higher the number of the ships arriving at the port, the higher is the percentage of time the berths are utilised (the lower the berth idle time) for a constant berthing capacity; and the higher the number of berths, the lower the berth utilisation (the higher the berth idle time) for handling a constant amount of cargo or number of ships.

Again Tables 6.14 to 6.17 were used to illustrate graphically the relationship between the number of ships and berth idle times for the general cargo traffic of Basra port, and between the number of berths and the percentage idle time for the rest of the cargo classes in the same port. The results obtained are shown in Figures 7.11 to 7.14 for general cargo, grain, oil and sugar traffic respectively.

Figure 7.11 shows that the percentage berth idle time decreases as the number of ships increases, that is, as the number of ships arriving at the port is increased, the berths are utilised more and more. When the percentage berth idle time approaches zero (utilisation approaching 100 per cent), congestion becomes chronic, implying that there is a continuous queue of ships waiting to occupy a berth immediately once it becomes empty. The other extreme, when the percentage idle time gets higher and higher as the number of ships arriving is decreased, indicates that the berthing capacity available is in excess of what is required and the berths are kept idle most of the time, waiting for a ship to arrive to provide the service.

The two extremes, when the percentage berth idle time is high, is associated with low average waiting times implying that more ships can be serviced by the same number of berths; and when the idle time is low which is associated with high average waiting times implying that the port is congested and more capacity should be provided or the number of ships (amount of cargo handled) should be reduced as can be seen from the tables.

Figures 7.12 to 7.14 show that, as the number of berths (berthing capacity) is increased, the percentage idle time is also increased, that is, they are less utilised and therefore less congested.

Tables 6.18, 6.21, 6.24 and 6.27 were used to obtain the Figures 7.15 and 7.16 for general cargo and container traffic in Um Qasr port, and Tables 6.30 and 6.31 were used to obtain Figures 7.17 to 7.20 for fertiliser, sulphur, urea and phosphate traffic. The results obtained from those figures are similar to the ones discussed above.

Another important thing about the percentage idle is that when the number of berths (berthing capacity) is very high (see for example, Figure 7.15 and Table 6.27) the percentage idle time approaches zero, that is the utilisation approaches 100 per cent, yet, the congestion is kept low, implying that the berths can be utilised for over 90 per cent of the time in this particular case. This last point makes it clear that conclusions drawn purely on the percentage berth idle time, or berth utilisation, are not as useful as those obtained from the average waiting time, since it is very difficult to decide on the appropriate percentage of berth idle time resulting in the appropriate berthing capacity required.

7.4 Maximum Queue Length

Another useful statistic provided by the simulation is the maximum queue length of ships reached during the simulation, queues of ships

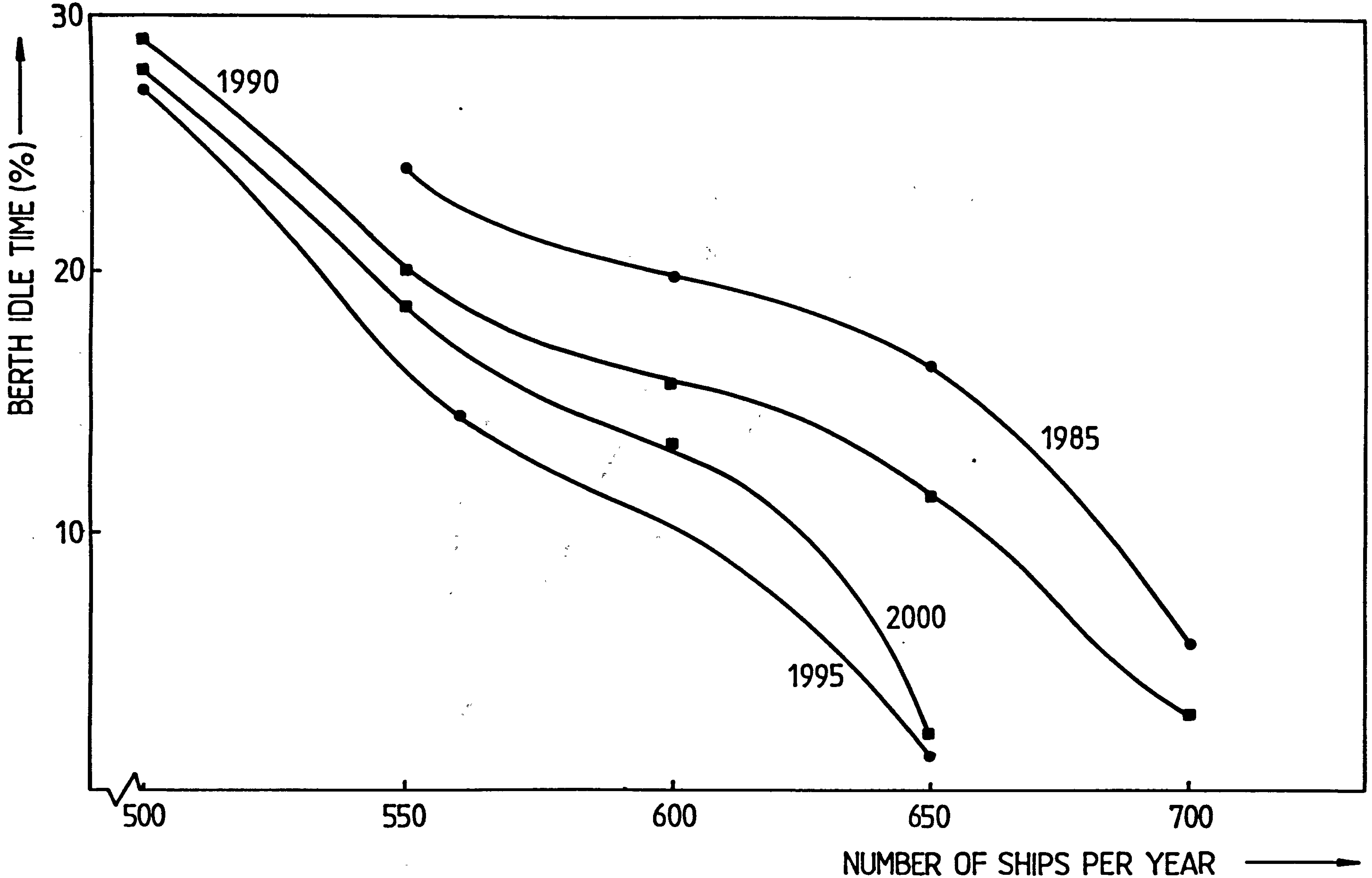


FIGURE 7-11 BASRA PORT, GENERAL CARGO TRAFFIC, MLF, BERTH IDLE TIME (%) V. NUMBER SHIPS ARRIVING / YEAR, BERTHS OPERATE 12 HOURS

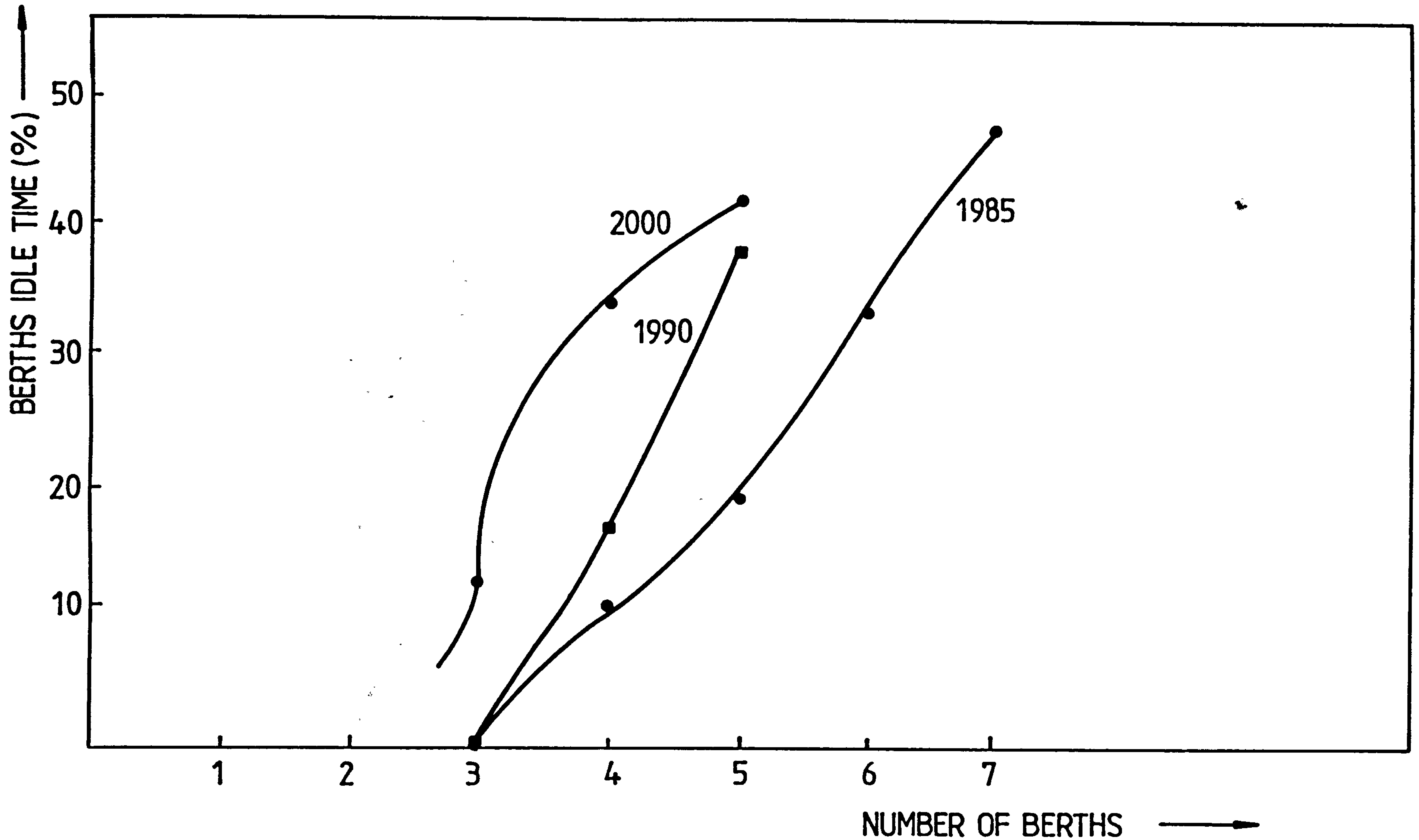


FIGURE 7-12 BASRA PORT, GRAIN TRAFFIC, MOST LIKELY FORECASTS, BERTH IDLE TIME (%) V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS.

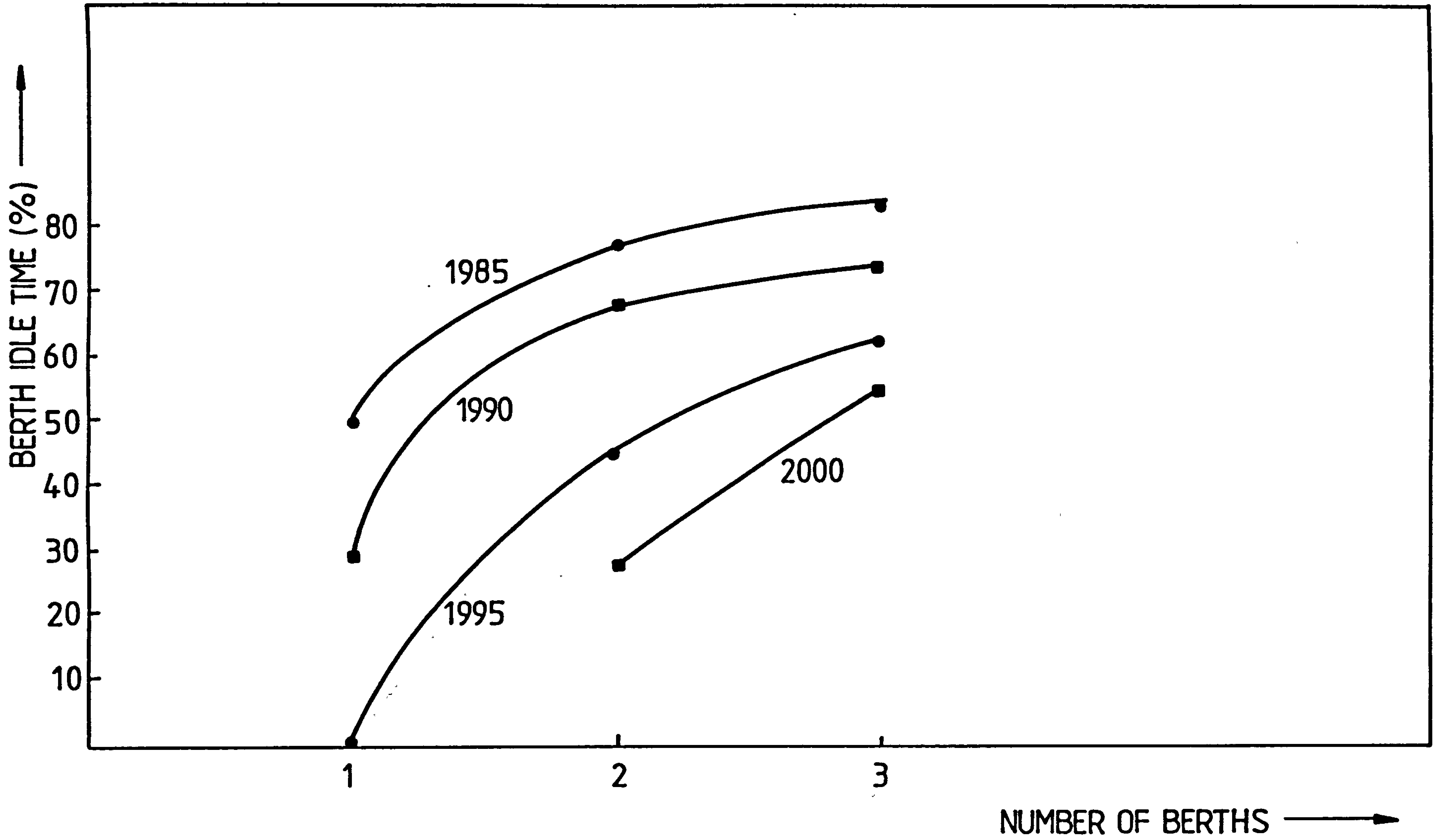


FIGURE 7-13 BASRA PORT, OIL TRAFFIC, MOST LIKELY FORECASTS, BERTH IDLE TIME (%) V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS

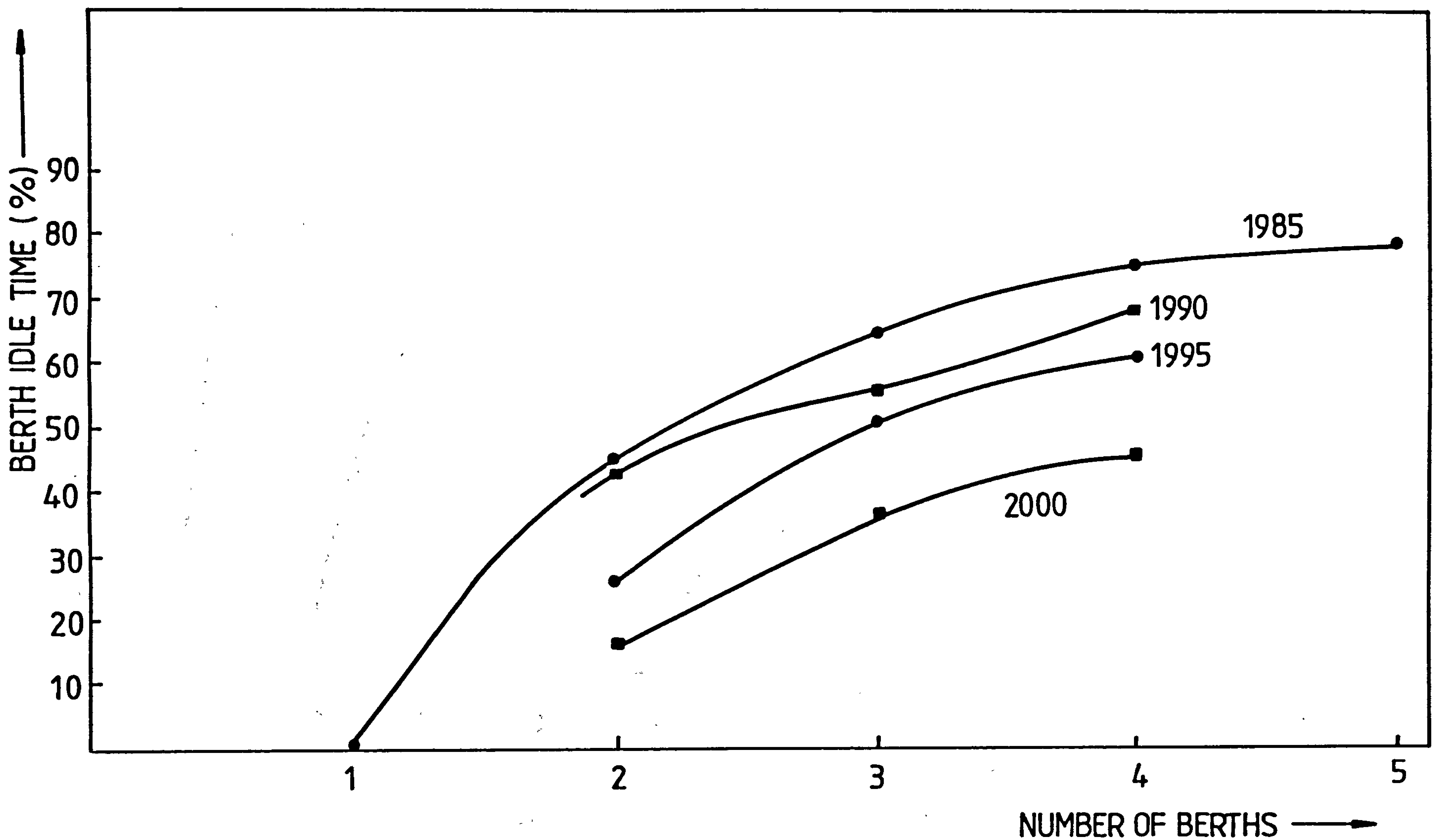


FIGURE 7-14 BASRA PORT, SUGAR TRAFFIC, MOST LIKELY FORECASTS, BERTH IDLE TIME (%) V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS

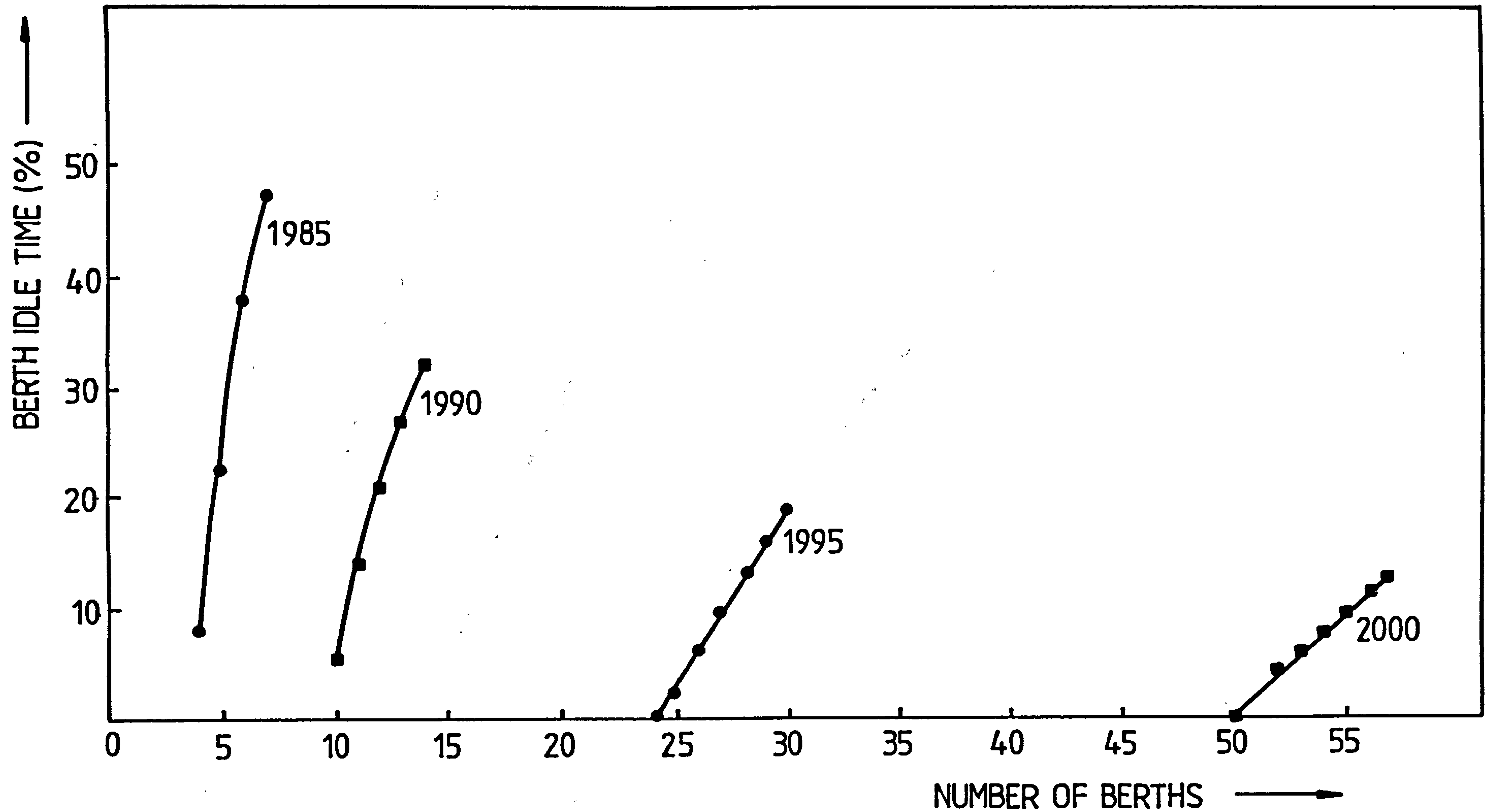


FIGURE 7-15 UM QASR PORT, GENERAL CARGO TRAFFIC, MLF, BERTH IDLE TIME (%) V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS.

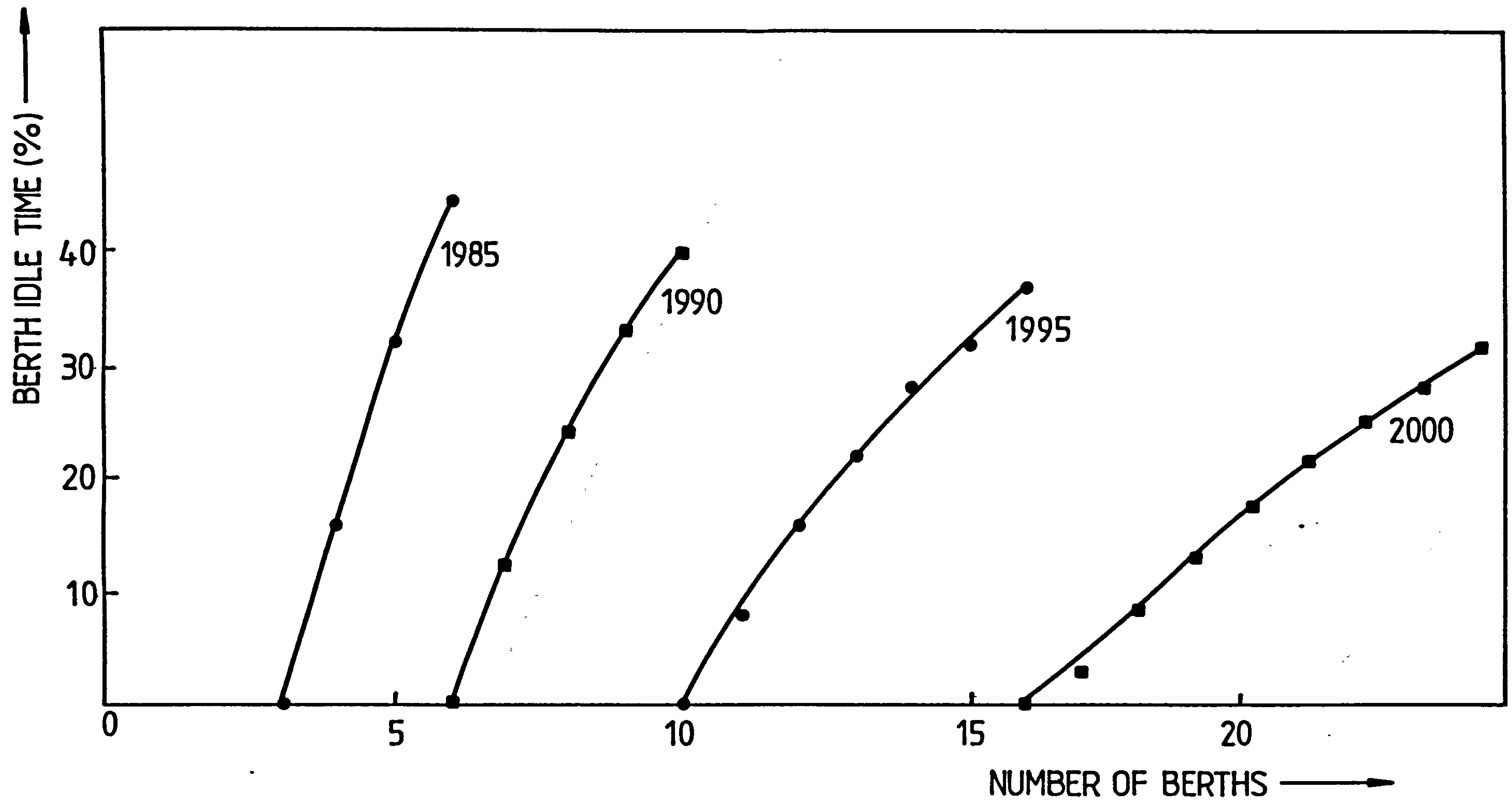


FIGURE 7-16 UM QASR PORT, CONTAINER TRAFFIC, MLF, BERTH IDLE TIME (%) V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS

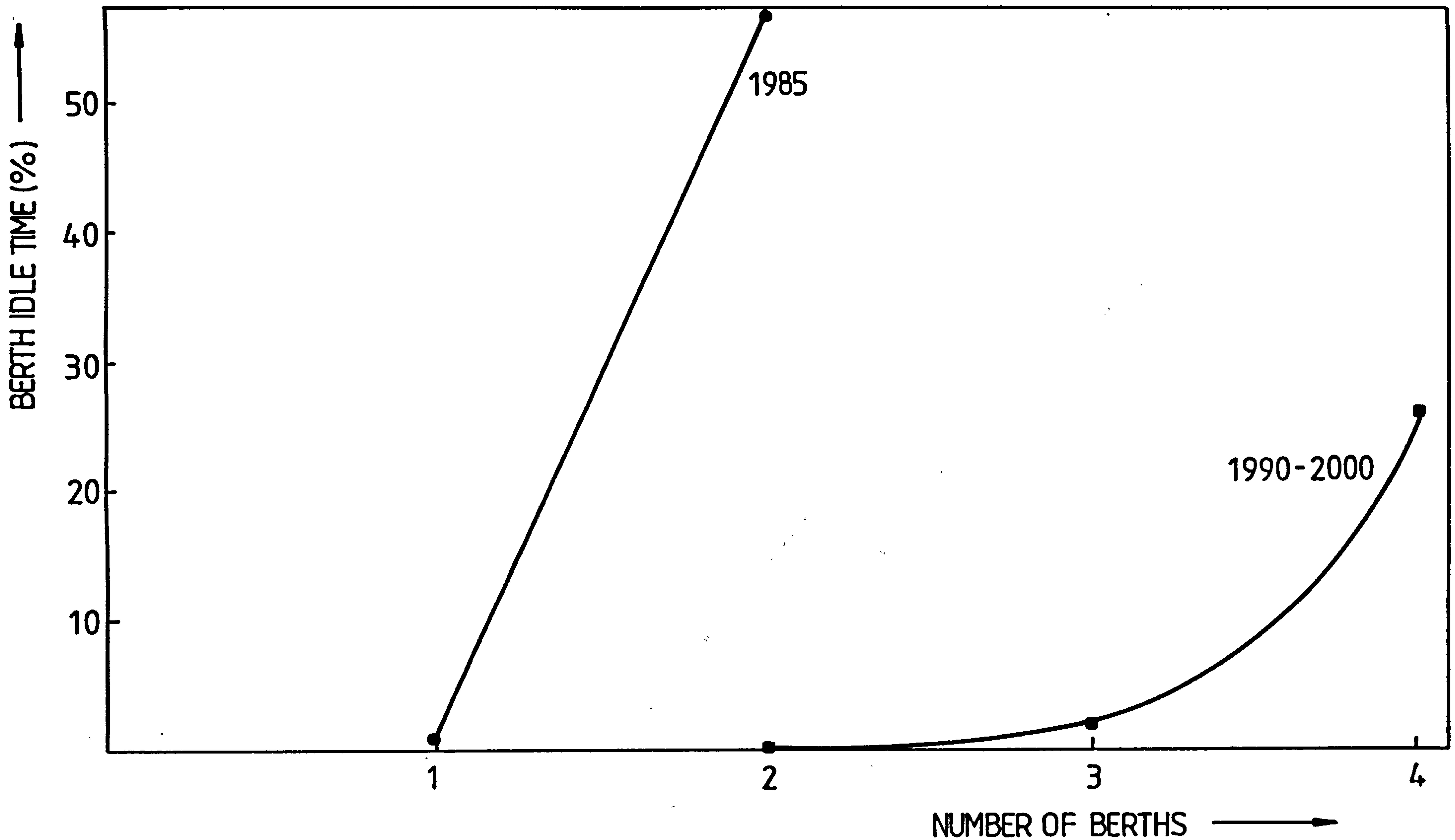


FIGURE 7-17 KHOR AL-ZUBAIR PORT, FERTILISER TRAFFIC, MLF, BERTH IDLE TIME (%) V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS.

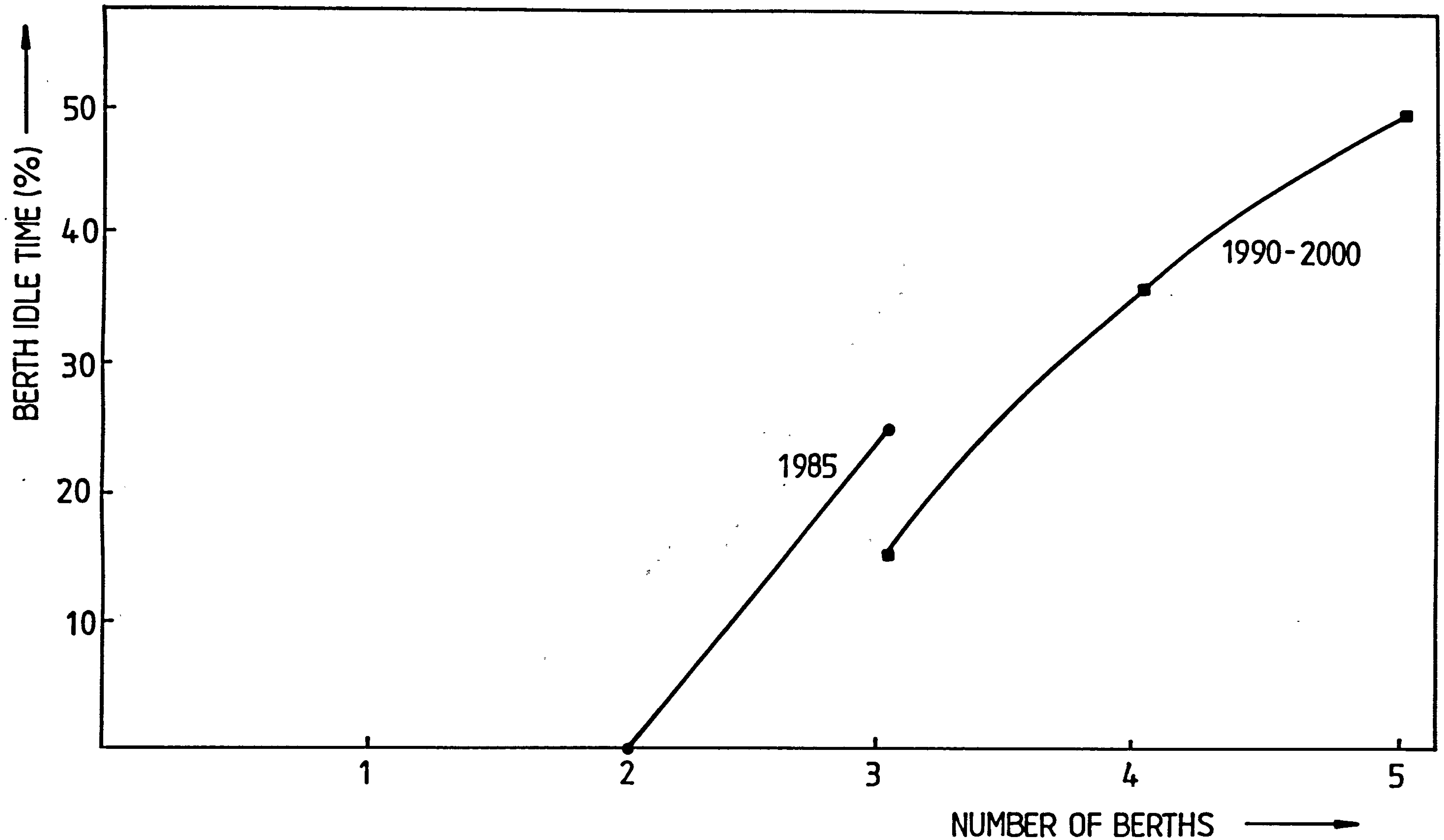


FIGURE 7-18 KHOR AL - ZUBAIR PORT, SULPHUR TRAFFIC, MLF, BERTH IDLE TIME (%) V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS.

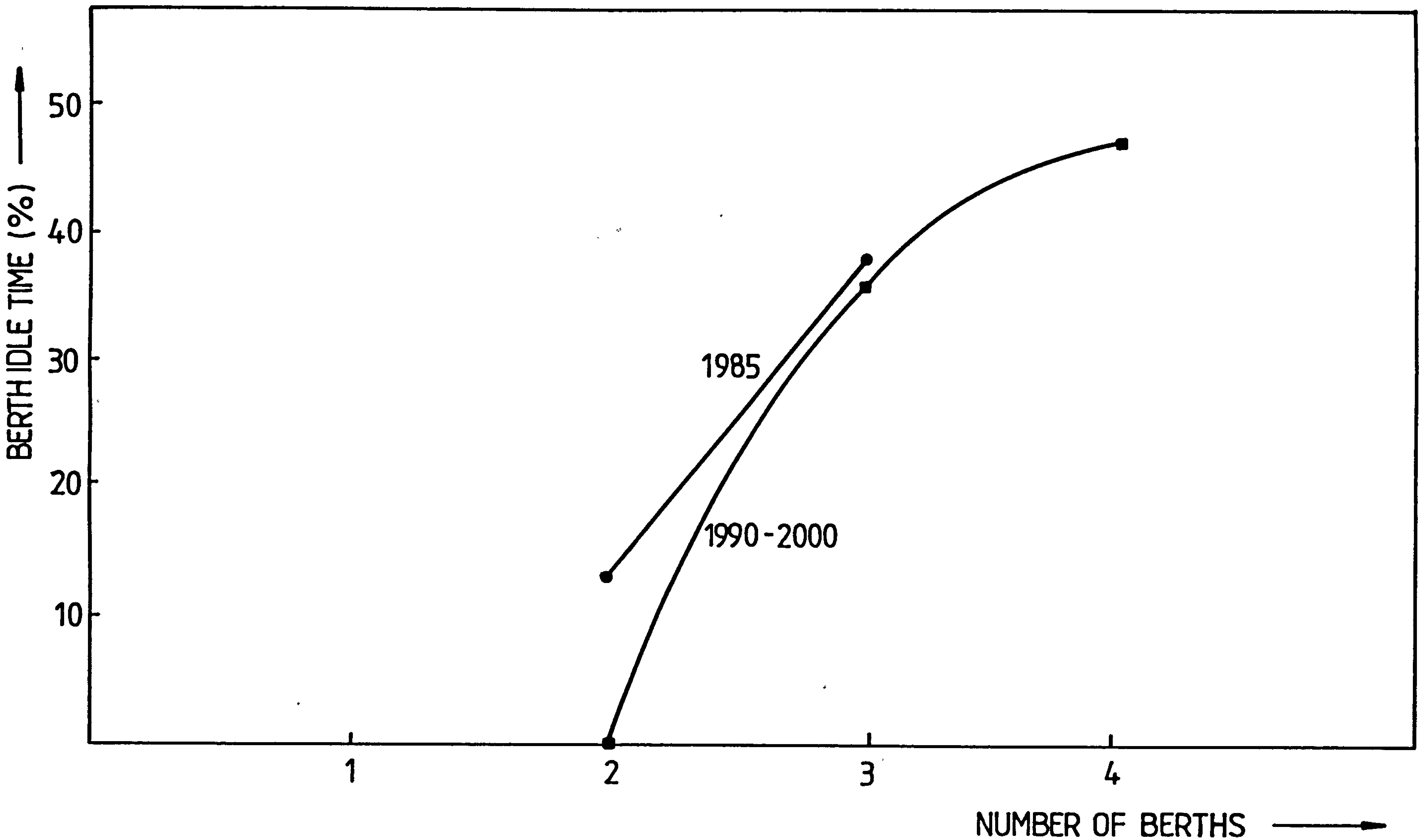


FIGURE 7-19 KHOR AL-ZUBAIR PORT, UREA TRAFFIC, MLF, BERTH IDLE TIME (%) V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS

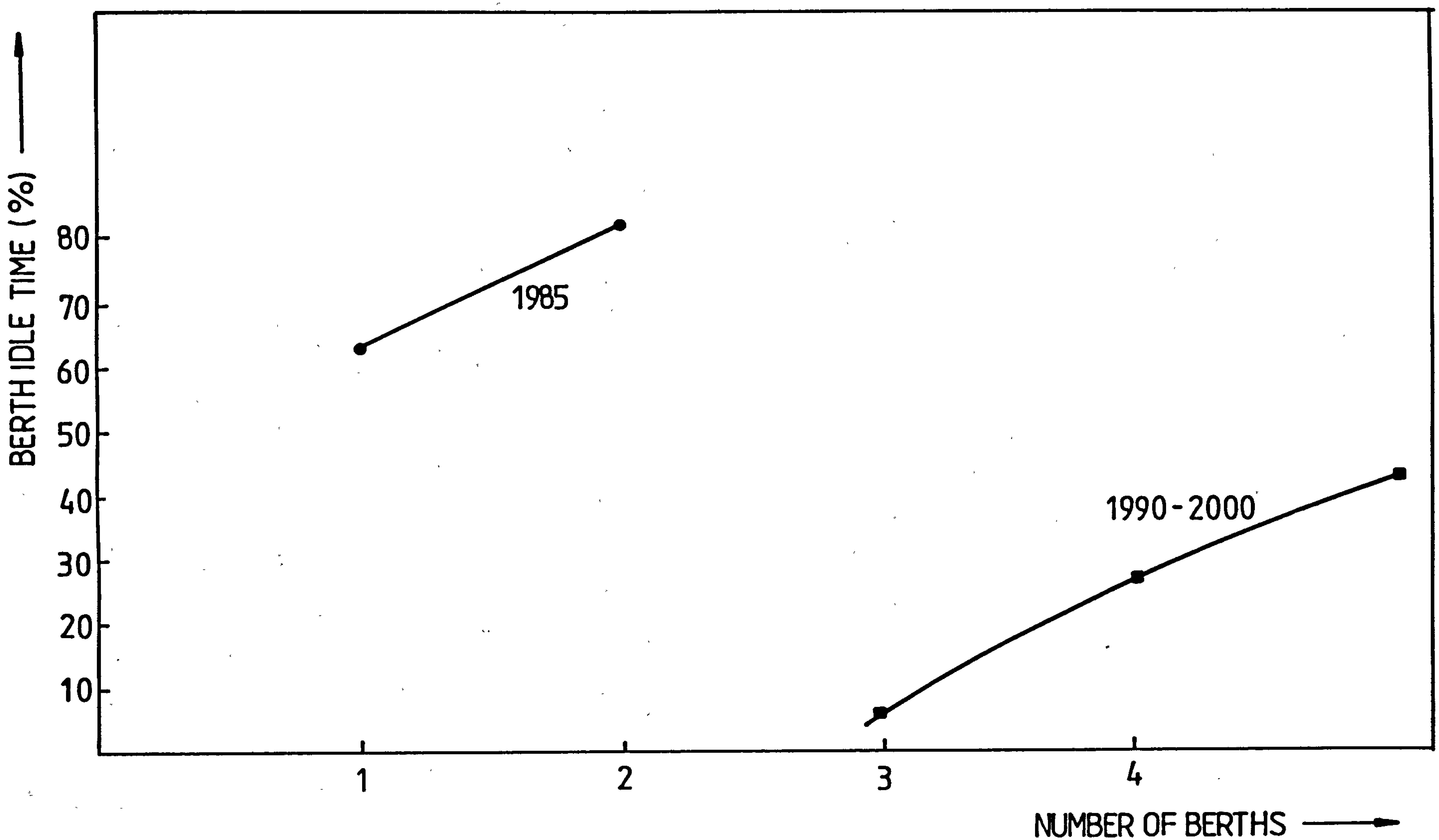


FIGURE 7-20 KHOR AL-ZUBAIR PORT, PHOSPHATE TRAFFIC, MLF, BERTH IDLE TIME (%) V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS

form in ports purely due to the random pattern of arrival, that is, if ships happen to arrive with little time interval between them and the number of berths available to service them is small, but with enough capacity to provide the required service, few ships will form a queue waiting their turn to receive service. In this case there is no danger of congestion because the amount of time the ships are in the queue is small. When the queue of ships continues to grow due to insufficient capacity, congestion becomes imminent. The longer the queue, the higher the congestion and in chronic cases, ships wait in the queue for long time periods, could be months or years before receiving service as cited in a few examples in Chapter 1.

The higher the number of ships arriving at the port, the longer is the queue of ships for a constant berthing capacity; and the higher the number of berths, the smaller is the queue, for a constant number of ships arriving in a particular year. Tables 6.14 to 6.17 were used to show how the maximum queue length of ships varies with the number of ships arriving for the general cargo traffic and with the number of berths for the rest of the cargo traffic in Basra port. The results are shown in Figures 7.21 to 7.24 for general cargo, grain, oil and sugar traffic.

Figure 7.21 shows that the maximum queue length increases as the number of ships arriving is increased and vice-versa. Just like the average waiting time, it increases gradually at small increments up to a point, beyond which the increase becomes very rapid, implying that congestion is getting higher and higher. The turning points in this curve, that is, when congestion starts getting high (a high number of ships is in the queue) is just over 650 ships for the years 1985 and 1990 and 600 ships for the years 1995 and 2000.

In Figures 7.22 to 7.24, the maximum queue length was plotted against the number of berths and the figures show that the queue length increases as the number of berths decreases and vice-versa, again, gradually up to a point and then rapidly beyond it.

Tables 6.18, 6.21, 6.24 and 6.27 were used to obtain Figures 7.25 and 7.26 for general cargo and container traffic respectively at Um Qasr port, and Figures 7.27 to 7.30 were obtained using Tables 6.30 and 6.31, for fertiliser, sulphur, urea and phosphate traffic respectively at Khor Al Zubair ports; the results obtained from those figures are similar to the ones discussed above.

Again this statistic provides useful guidelines to the port planner, for example, if we look at Figure 7.21, we can tell that the queue length is small when 550, 600 and 650 ships arrive, implying that 650 ships can be serviced by the 15 berths with little congestion; on the other hand, the figure shows that when 700 ships or over arrive at the port, congestion increases at a very fast rate, implying that approximately between 650 and 700 ships can be accomodated by the 15 berths in 1985.

In addition to the statistics discussed above, the simulation provides waiting time distributions, idle time distributions and queue length distributions (see for example, the last page of the output for Khor Al Zubair port 1985 shown in Chapter 6).

More information can be obtained from those distributions, for example, the last three columns of the output, Tables 6.11 to 6.39, show the number of ships (for each class of cargo) waiting for over 24 hours, over 120 hours, and over 240 hours and decisions based on such results can be made, for example, no more than X ships should be allowed to wait over 1 day, or, no more than Y ships should be allowed to wait over 5 days ... etc., yet all those decisions are approximate and serve as useful guidelines.

Since the penalties paid by the port authorities are purely on the amount of time the ship waits before receiving service, the average waiting time per ship remains to be the most useful statistic for evaluation purposes and in Chapter 8 it will be used to determine the optimum number of berths required for each class of cargo in future time periods.

As was illustrated in the three sections of this chapter, the average waiting time per ship and the queue length decreases as the number of berths is increased, and so will the berth idle time. This information forms the basis for the minimum cost point model used in the evaluation in the next chapter.

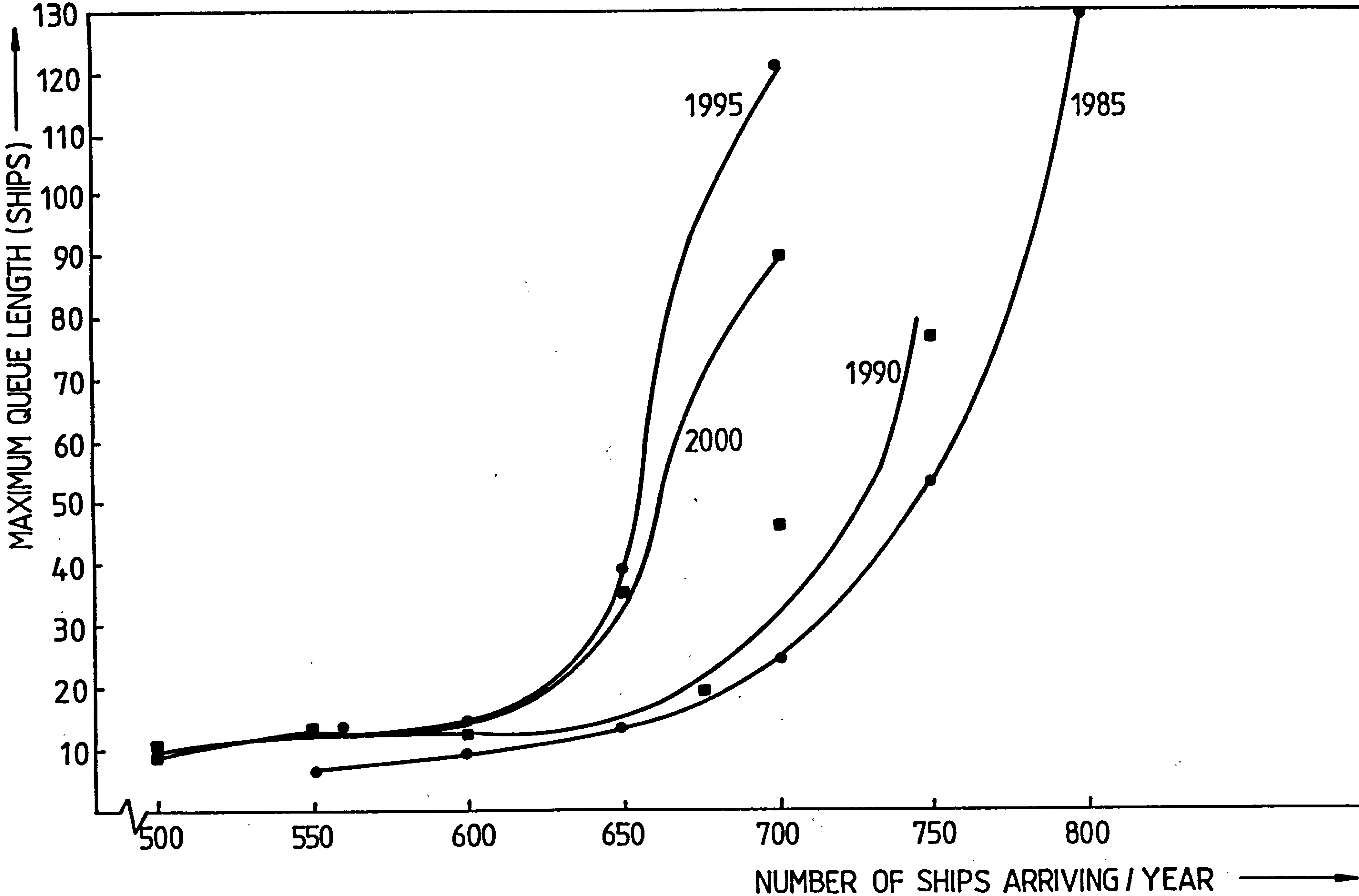


FIGURE 7-21 BASRA PORT, GENERAL CARGO TRAFFIC, MLF, MAXIMUM QUEUE LENGTH V. NUMBER OF SHIPS ARRIVING / YEAR, BERTHS OPERATE 12 HOURS

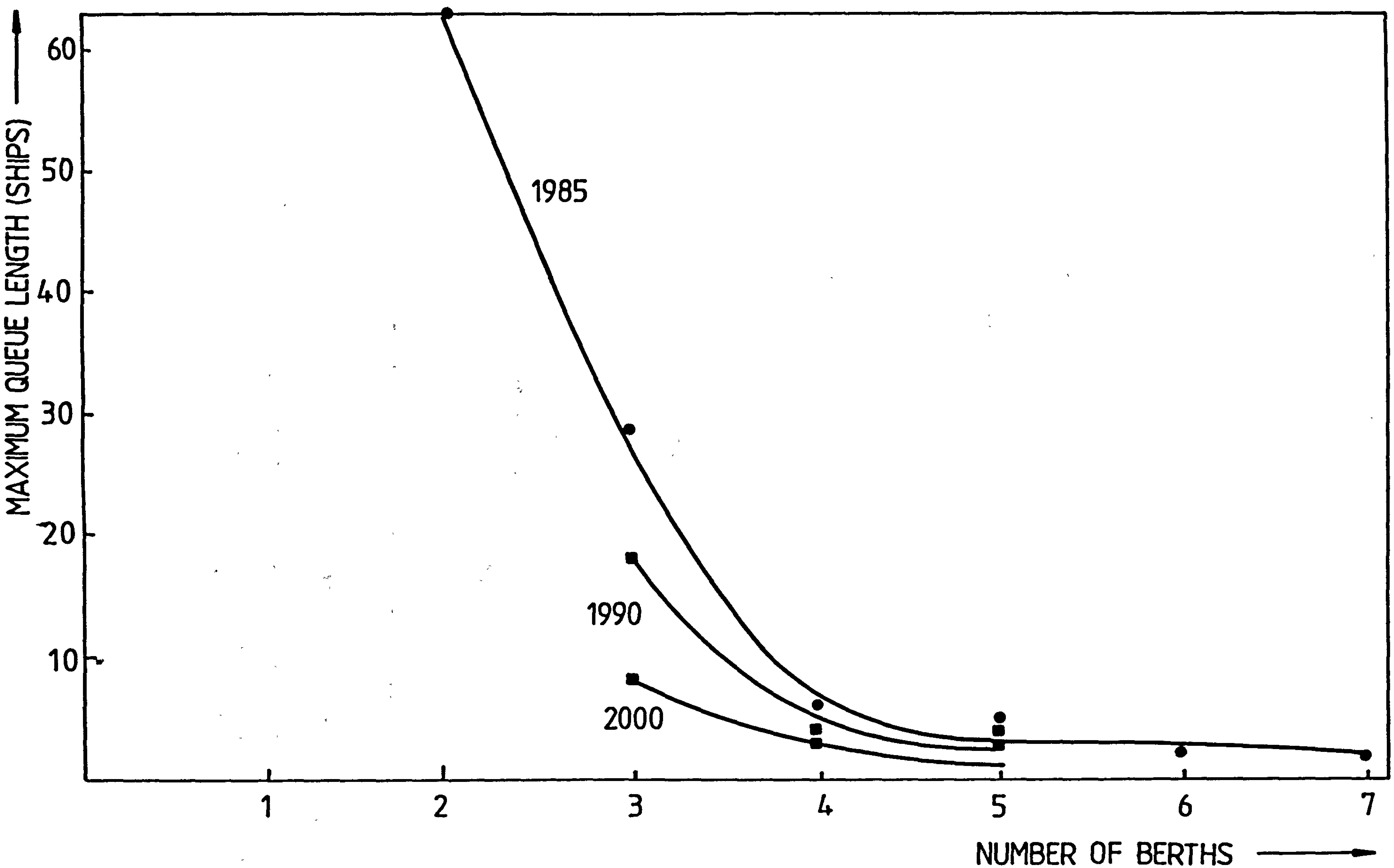


FIGURE 7-22 BASRA PORT, GRAIN TRAFFIC, MLF, MAXIMUM QUEUE LENGTH V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS

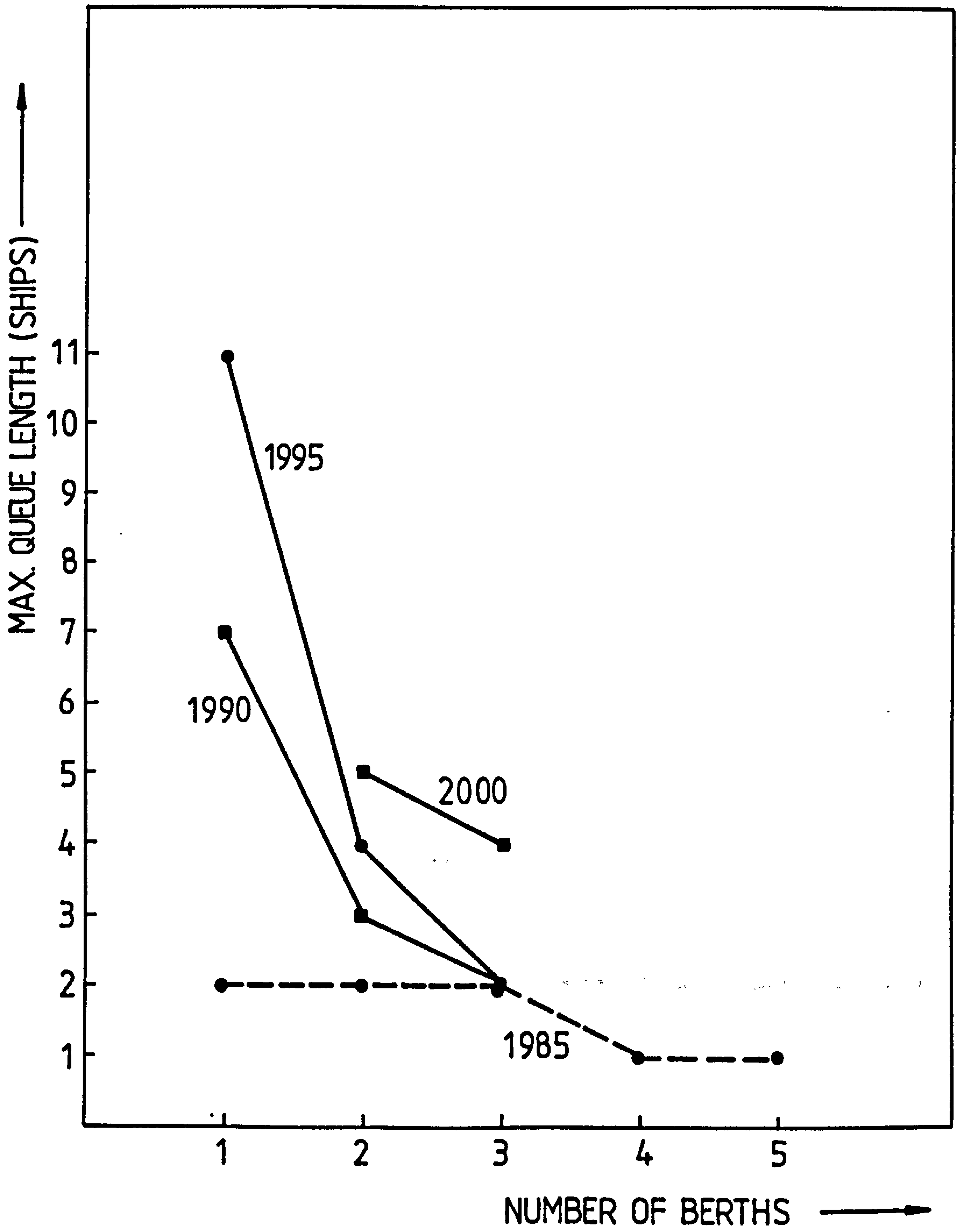


FIGURE 7-23 BASRA PORT, OIL TRAFFIC, MLF, MAX. Q.L. (SHIPS) V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS..

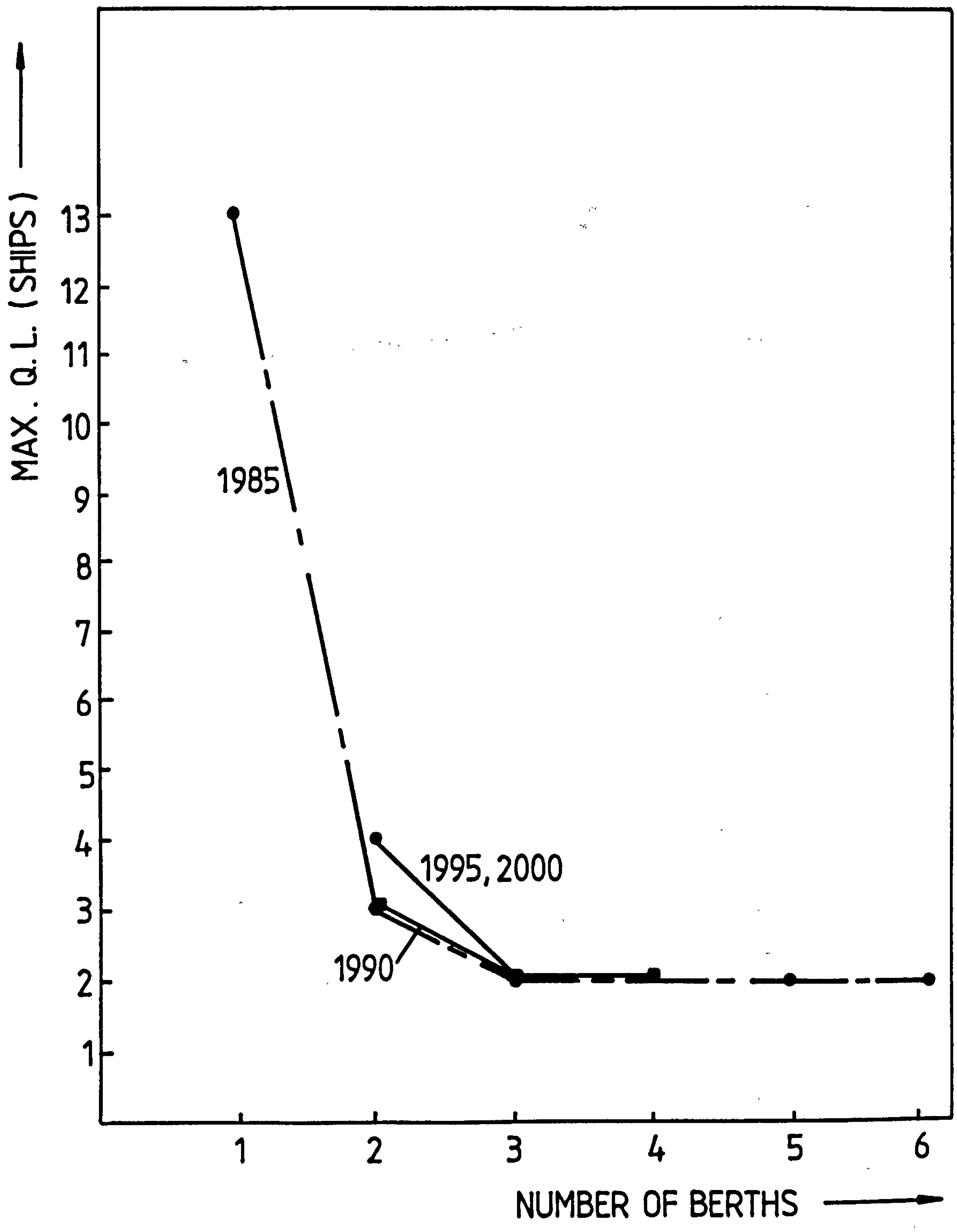


FIGURE 7-24 BASRA PORT, SUGAR TRAFFIC, MLF, MAX. Q.L. (SHIPS) V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS.

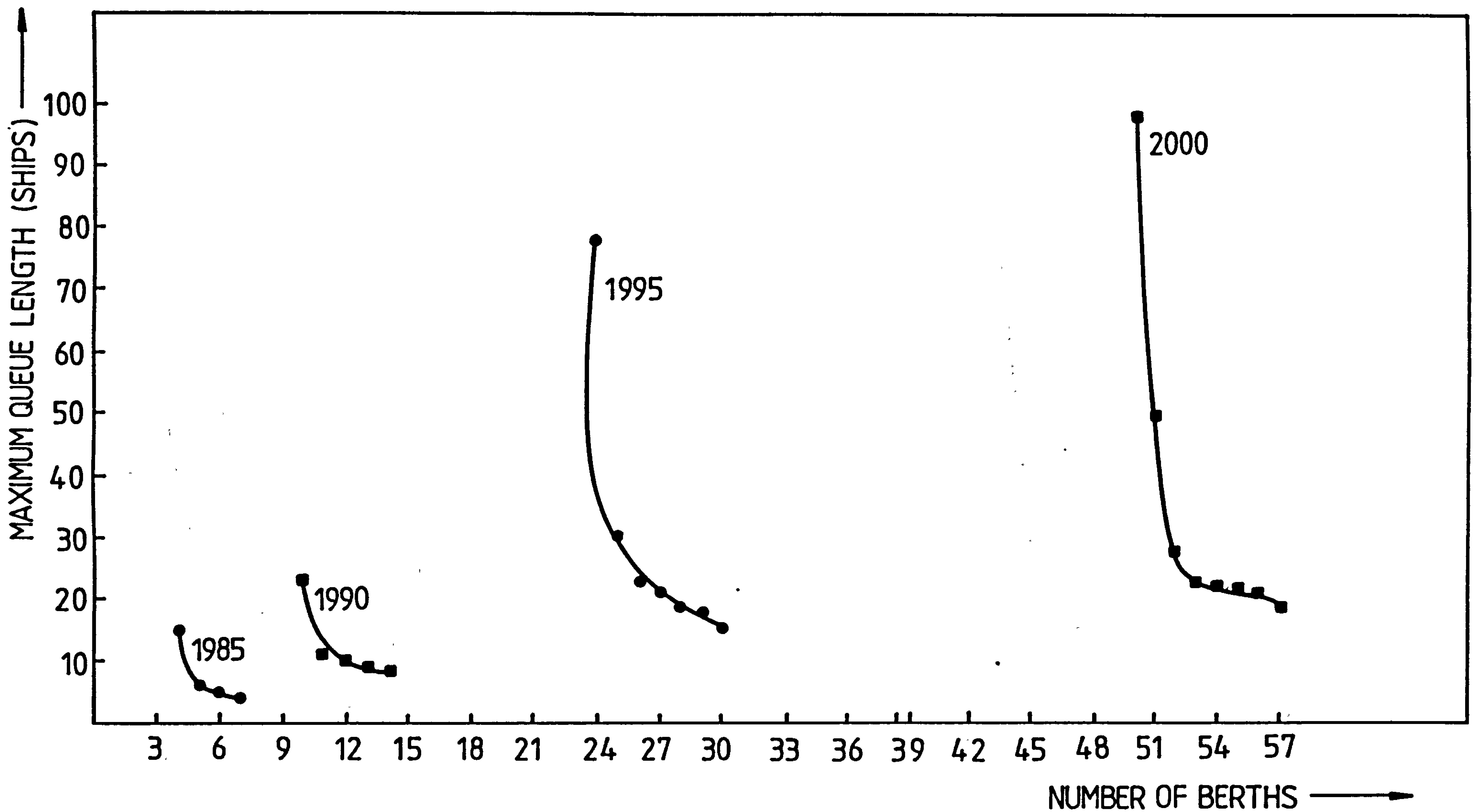


FIGURE 7-25 UM QASR PORT, GENERAL CARGO TRAFFIC, MLF, MAXIMUM QUEUE LENGTH (SHIPS) V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS

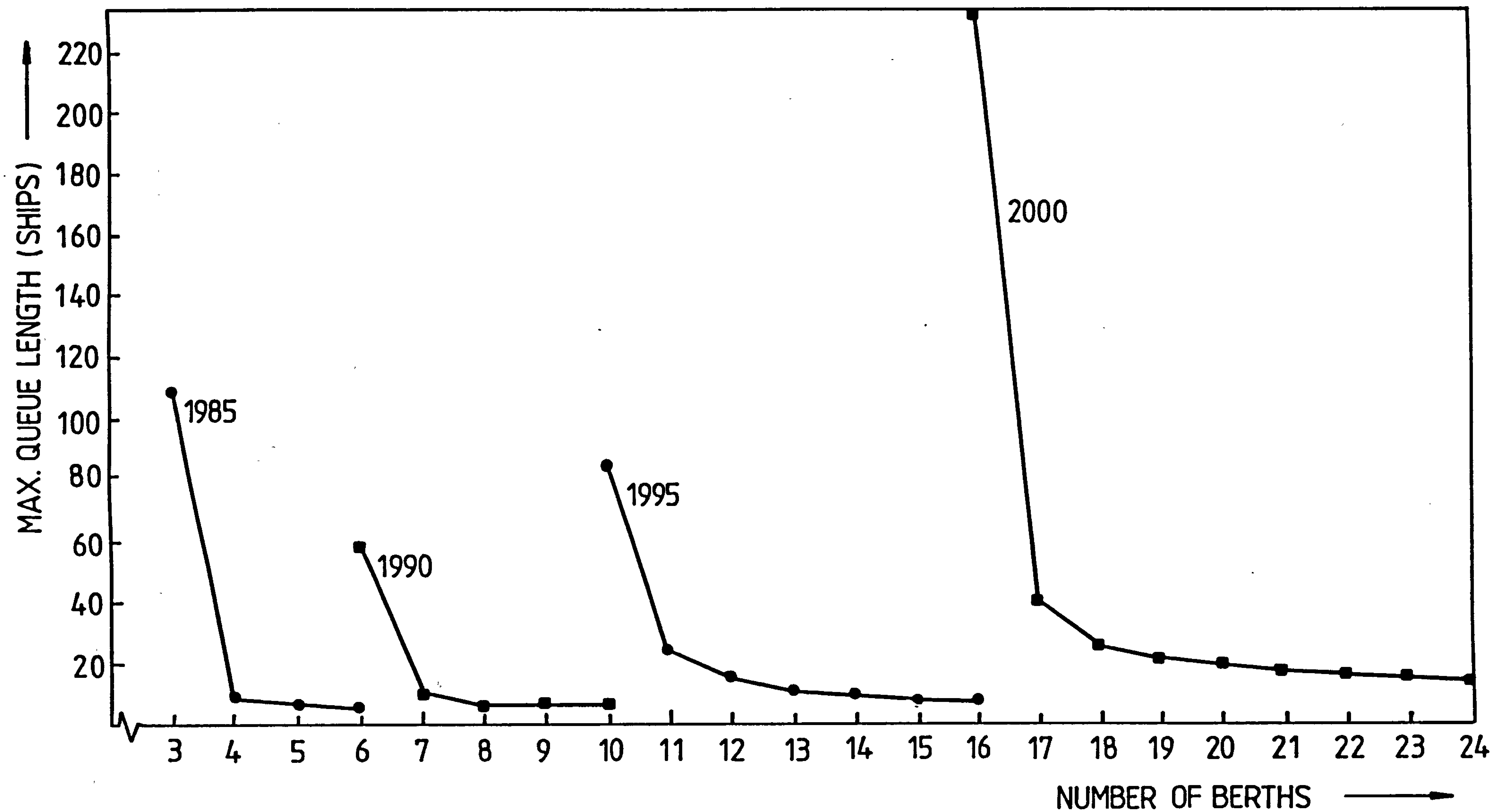


FIGURE 7-26 UM QASR PORT CONTAINER TRAFFIC, MLF, MAXIMUM QUEUE LENGTH (SHIPS) V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS

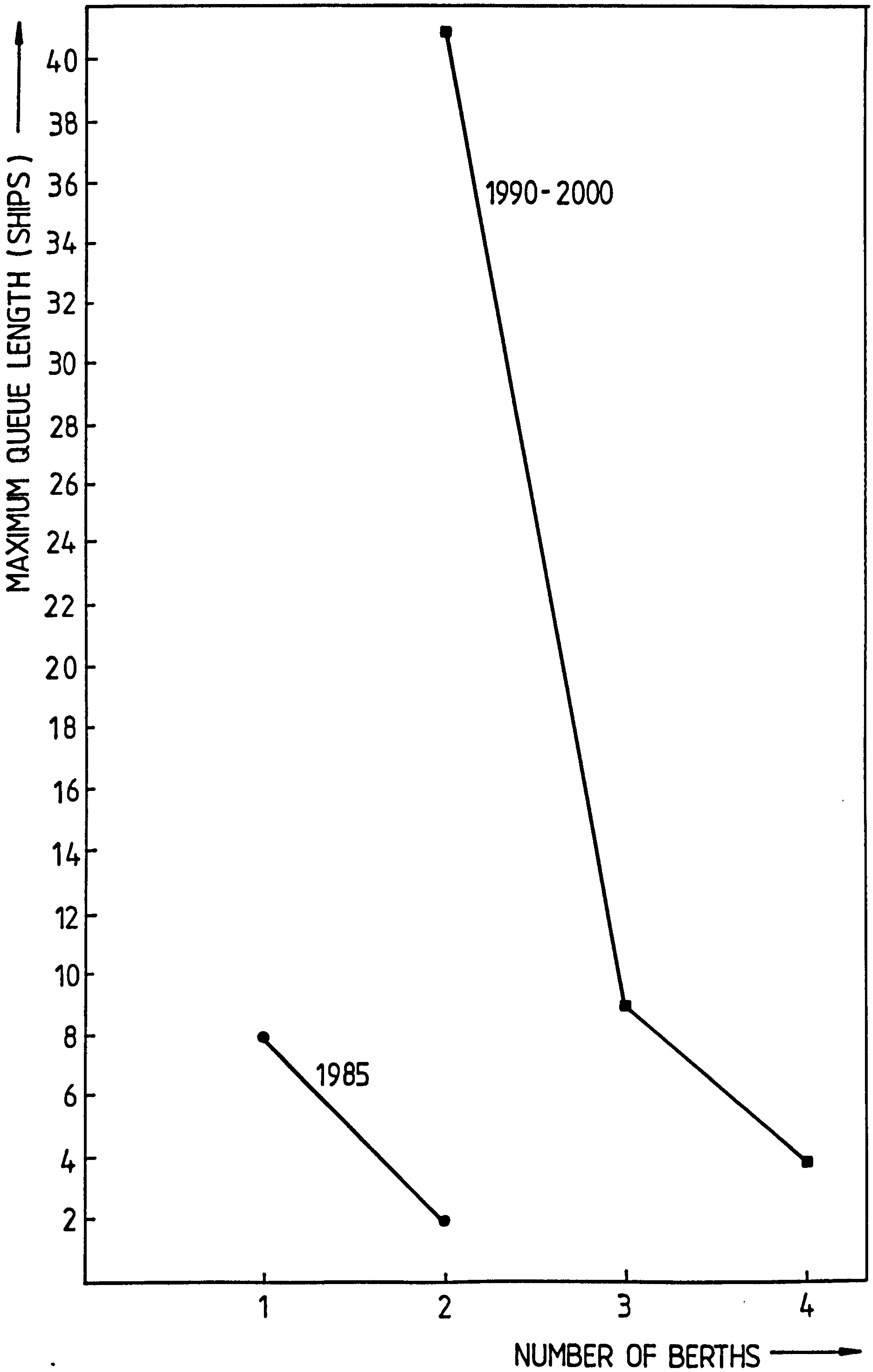


FIGURE 7-27 KHOR AL-ZUBAIR PORT, FERTILISER TRAFFIC, MLF, MAX Q.L. (SHIPS) V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS.

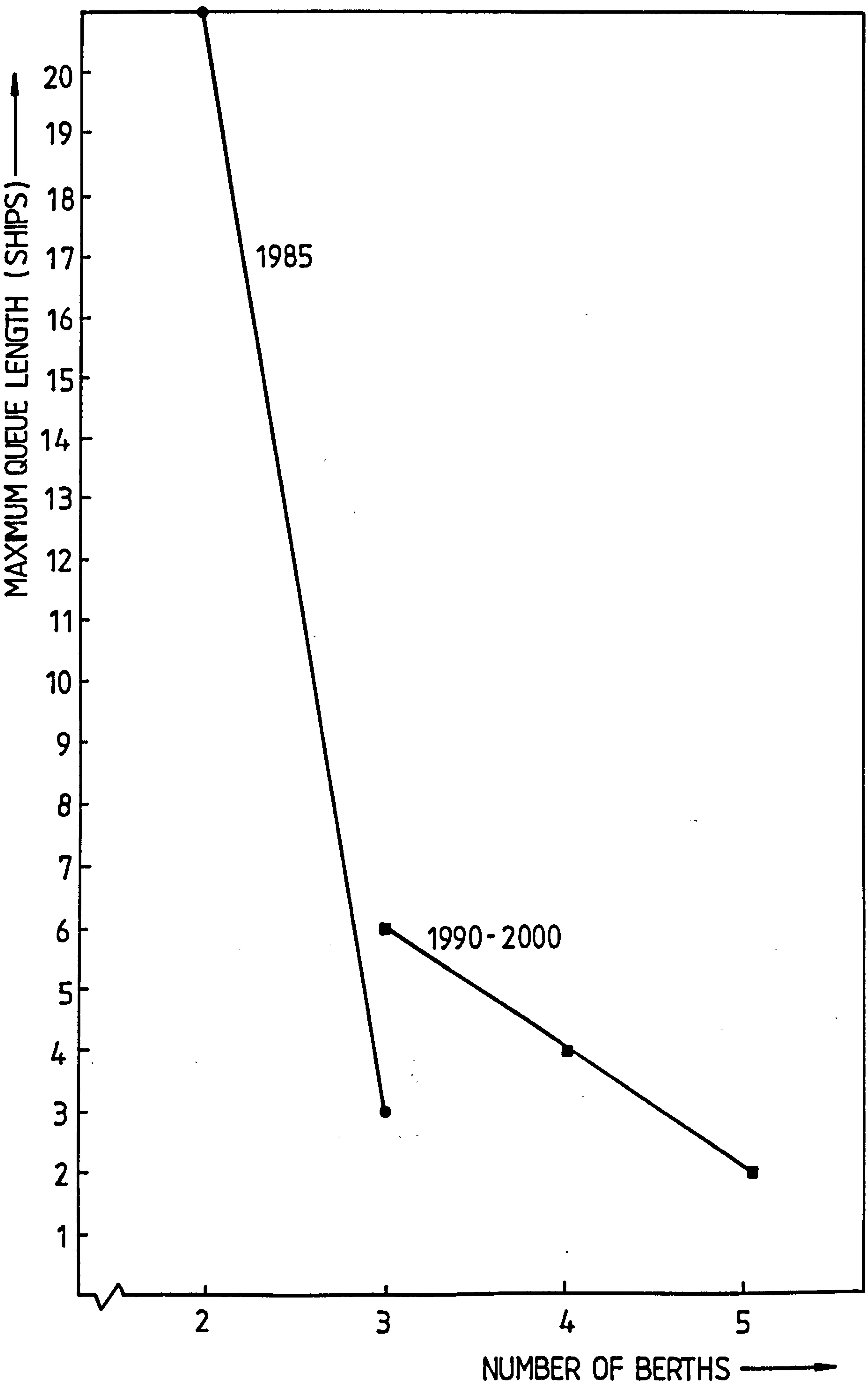


FIGURE 7-28 KHOR AL-ZUBAIR PORT, SULPHUR TRAFFIC, MLF, MAX.Q.L. (SHIPS) V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS.

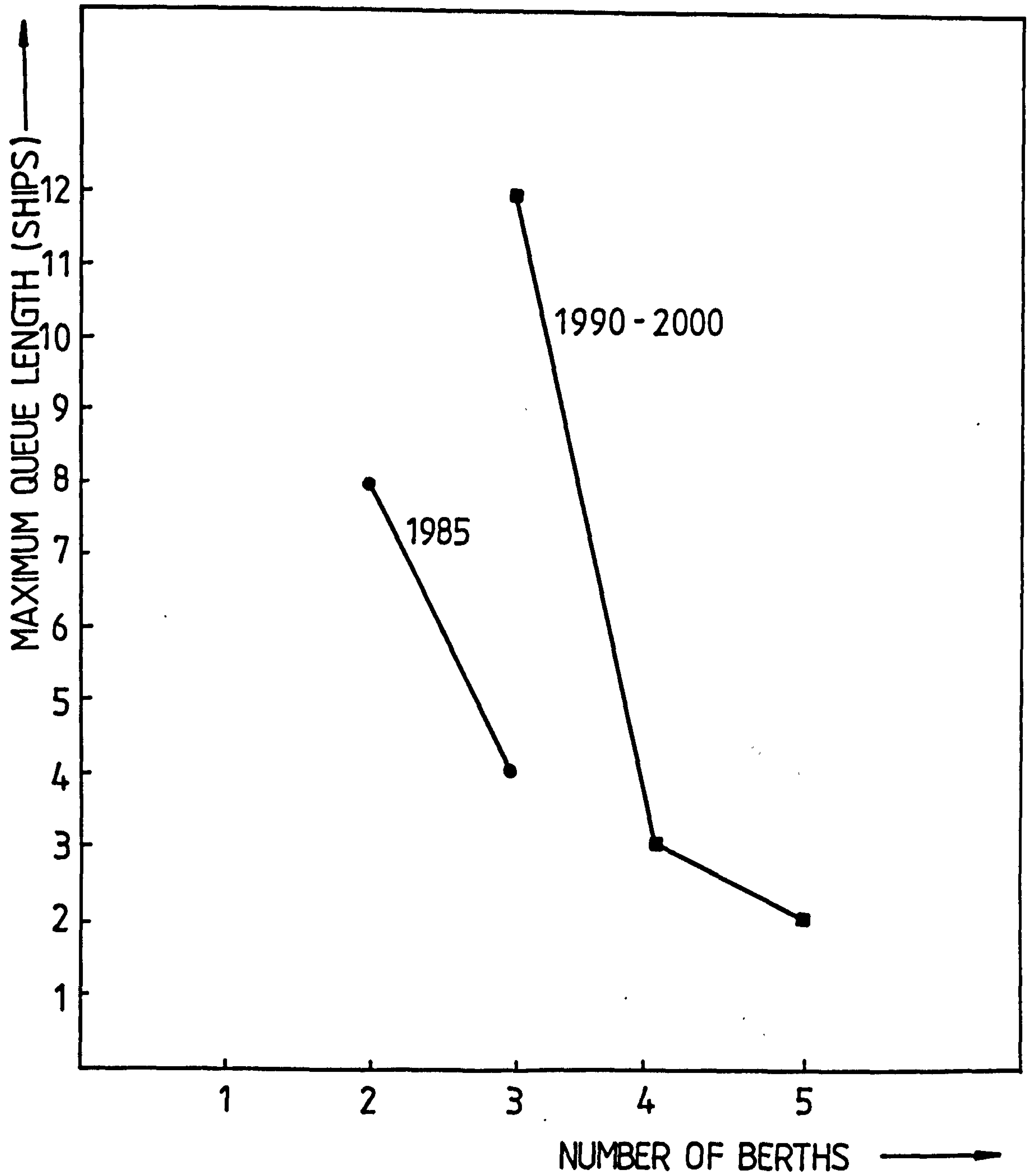


FIGURE 7-29 KHOR AL-ZURAIR PORT, UREA TRAFFIC, MLF, MAX. Q.L. (SHIPS) V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS.

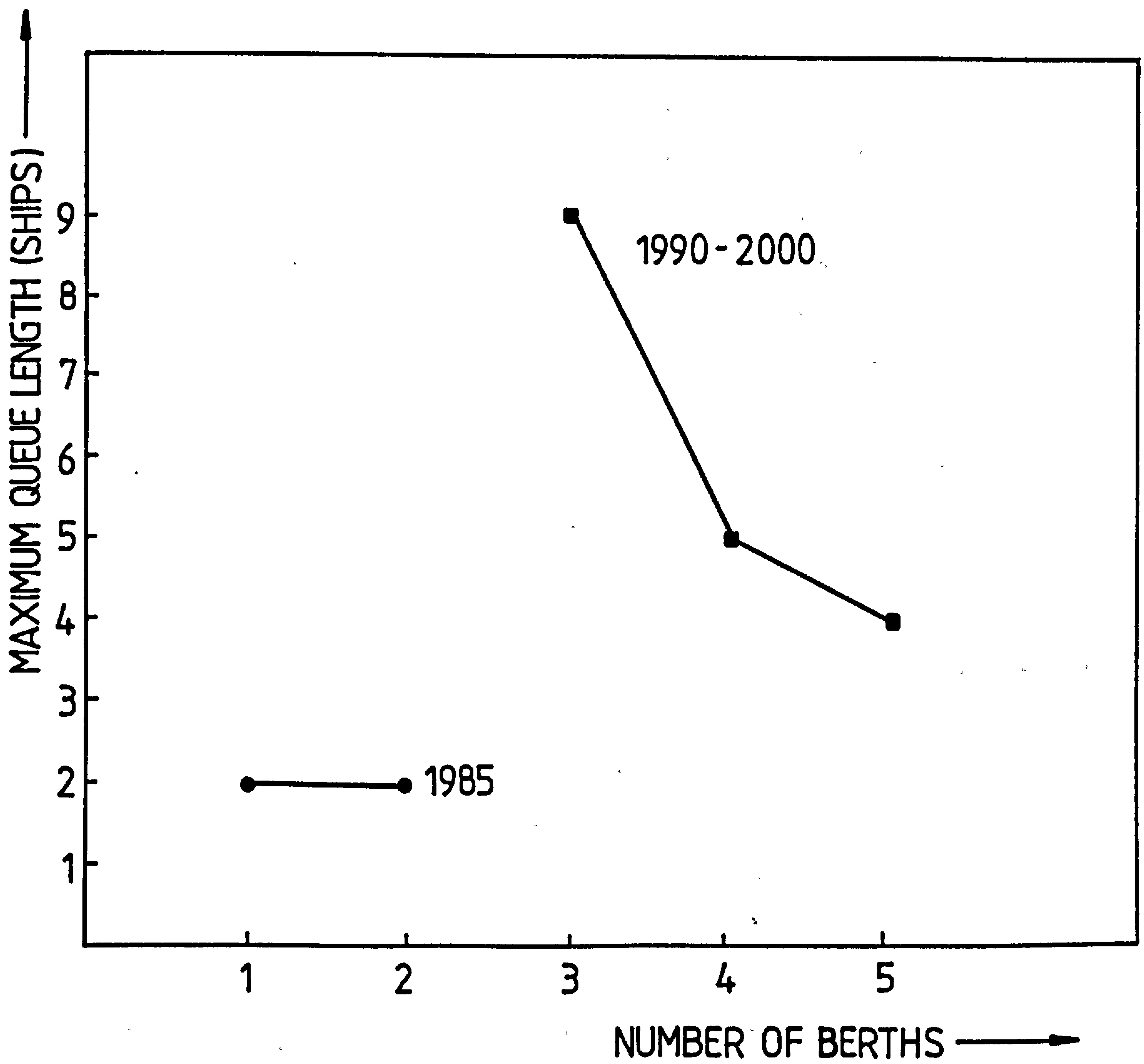


FIGURE 7-30 KHOR AL-ZOBAIR PORT, PHOSPHATE TRAFFIC, MLF, MAX.Q.L. (SHIPS) V. NUMBER OF BERTHS, BERTHS OPERATE 12 HOURS

CHAPTER 8

INVESTMENT APPRAISAL

8.1 Introduction

The final and most important phase in port planning is investment appraisal which enables us to determine the optimum number of berths required to cater for future demand for each class of cargo. It was illustrated in Chapter 3 of this study that a very high berth occupancy could only be guaranteed at the expense of a continuous queue of ships. Similarly, that ships would never have to wait before being able to berth, could only be guaranteed at the cost of extremely low average berth occupancies. Neither of these two alternatives is acceptable, the optimum capacity for the port will be attained by balancing the gains of reducing congestion against the cost of doing so.

Congestion can be relieved either through limiting the number of ships arriving at the port if the berthing capacity is constant and cannot be increased further (as in the case of general cargo berths at Basra port), or, more frequently through increasing the berthing capacity by providing more berths (as in the case of the rest of the berth groups at all three ports) when demand is increasing.

Like any other project, costs are incurred through investments and certain benefits are expected in return. In port planning projects, investment costs arise from constructing new berths and the sheds, warehouse, cranes ... etc. that go with them, plus the cost of maintenance and operation. The benefits obtained from the project are generated through reducing congestion and hence minimising the amount of money paid in waiting costs as penalties. As congestion is reduced, so is the amount of time cargo stays on board the ship where it is needed in the country, it is very difficult to quantify this last benefit (reduced amount of time cargo stays on board the ships) since this usually depends on what the cargo is and how urgently it is required, but nevertheless, it can be appreciated that in addition to reducing the penalties paid in waiting costs as congestion is reduced, proper use can be made of the cargo imported as required.

In Section 4.4 of Chapter 4, it was mentioned that the costs and benefits arising from the project should be compared and the net present value obtained, if the NPV (net present value) is positive, then the investment should be made, that is, more berths should be constructed to reduce congestion which means, that the port is better off if more berths are constructed as will be seen later in this chapter. It was also mentioned in the same section, that while the use of NPV will lead to an optional investment policy for the time periods simulated (1985, 1990, 1195 and 2000) a new model has to be developed in order to arrive at an optimal berthing capacity at any future time period, for example, 1992, 1993, 1998 ... etc., especially when demand is increasing at a rapid rate, without having to perform additional thousands of calculations and simulations to obtain the forecasts and investment evaluations required on a year by year basis, this will be discussed in Section 8.4.

In order to make an evaluation of the costs and benefits arising from further investment in berths, the waiting costs of ships (the amount of money each ship type costs the port authority, paid in penalties as waiting costs) and the capital costs (construction costs plus operation and maintenance costs) are required. These costs are shown in Table 8.1.

TABLE 8.1 SHIPS OPERATING COST IN PORT AND BERTH'S CAPITAL COST(1) FOR 1985 ONWARDS

VESSEL CLASSIFICATION	AVERAGE SHIP LOAD (TON)	WAITING COST PER SHIP PER DAY (I.D.)[1]	CAPITAL COST PER BERTH (I.D.)[1]	MAINTENANCE AND OPERATION COST (I.D.)[2]
GENERAL CARGO	5,000 5,250 5,500 6,000	1,500 1,500 1,500 1,500	8,000,000	120,000
GRAIN	20,000	1,100	12,000,000	180,000
SUGAR	10,000 15,000 20,000	950 1,000 1,100	12,000,000	180,000
OIL	10,000 15,000 20,000	950 1,000 1,100	11,000,000	165,000
CONTAINER	2,500 3,000	2,500 2,500	23,000,000	345,000
FERTILISER UREA, SULPHUR AND PHOSPHATE	10,000 15,000 20,000	950 1,100 1,100	13,000,000	195,000

1 General Organisation for Ports (I.D. = Iraqi Dinars)

2 Maintenance and operation cost estimated at 1.5 per cent of the construction cost for a 12 hour day.

Columns 1 (vessel classification) and 2 (average ship load) of Table 8.1 show the types of cargo and the quantity carried by each vessel respectively (see section 5.9, Tables 5.18, 5.20 and 5.21 to 5.23 of Chapter 5) during the planning period.

Column 3, waiting cost per ship per day, that is, daily operating cost of ship in port, was given by the Port Authority and it is appropriate to check if these penalty costs are realistic. This can be achieved by calculating the daily operating costs directly from operating cost data, (Gilman 1977) has worked out these daily operating costs for 4 different types of general cargo ships as shown in Table 8.1a.

Table 8.1a Daily Operating Costs. Four Non-Cellular General Cargo Vessels

Code	C1	C2	C3	C4
Deadweight	14000	8000/12000[3]	23200	16500[5]
Gross tonnage	8800	9000[4]	17000	10864
Service speed (knots)	14	18	16	14
	U.S.$	U.S.$	U.S.$	U.S.$
Capital cost	9.2m	10.6m	17.6m	2.3m
Capital charge/day[1 2]	3626 (2805)	4177 (3231)	6936 (5366)	1233 (954)
Insurance/day	202	196	351	183
Crew wages and prov/day[6]	1259	1341	1259	1950
Maintenance and repair/day[7]	367	430	556	493
Daily fixed cost	2454	6144	9102	3859
Fuel in port/day	275	506	583	285
Daily in port costs	5729 (4908)	6650 (5704)	9685 (8115)	4144 (3865)
Fuel at sea/day[8]	1899	3086	3543	2120
Daily at sea costs	7353 (6532)	9230 (8284)	12645 (11075)	5979 (5700)

C1 = Liberty Replacement
C2 = Modern Liner
C3 = Large Modern Liner
C4 = Second Hand

[1] 350 operating days per annum
[2] Capital charge calculated as an annuity over 18 years at 12% rate of return
[3] Open closed shelter decker ship
[4] GRT corresponding to full deadweight
[5] 11 years old
[6] Crew costs for European crew
[7] All slow speed diesels
[8] Fuel includes lubricating oil consumption

Figures in brackets are with capital charges at 8%.

Looking at the average ship load for general cargo (see Table 8.1), the large modern liner is not likely to come to the Iraqi ports because it is too big, and any of the other three ships could come to the ports especially the second hand, C4, where they are routed to developing countries. Converting the daily in port costs for C1, C2 and C4 to Iraqi Dinars (I.D. = \$3.333, see section 2.1 of Chapter 2) we get:

	C1	C2	C4
Daily in port costs	1718(1472)	1995(1711)	1243(1159)

with an average of 1652(1447) which is very close to I.D. 1500 shown in Table 8.1 provided by the Port Authority probably assuming that more second hand, C4, general cargo ships than C1 and C2 call at the port.

The daily operating costs (Gilman 1977) for containers are shown in Table 8.1b.

Table 8.1b Daily Operating Cost - Cellular Containerships

Code	CT1	CT2
Deadweight	12000 (560 TEU)	23400 (1200 TEU)
Gross tonnage	11000	27000
Service speed (knots)	19	22
	U.S.$	U.S.$
Capital cost	18.1m	28.6m
Capital charge/day[1 2]	7133 (5518)	11270 (8718)
Insurance/day	385	770
Crew wages and prov./day[3]	1232	1386
Maintenance and repair/day[4]	493	781
Daily fixed cost	9243	14207
Fuel in port/day	350	800
Daily in port costs	9593 (7978)	15007 (12455)
Fuel at sea/day[5]	3325	8750
Daily at sea costs	12568 (10953)	22957 (20405)

1 350 operating days per annum
2 Capital charge calculated on an annuity over 18 years at 12% rate of return
3 Crew costs for European crew
4 All geared medium speed diesels
5 Fuel include lubricating oil consumption

Figures in brackets give costs at a discount rate of 8%.

Again CT2 is too large to call at the Iraqi ports (see Table 8.1).

Converting the daily in port costs for CT1 to Iraqi Dinars, we get:

Daily in port costs	CT1
	2878(2393)

which is very close to I.D. 2500 shown in Table 8.1.

The other waiting costs for other types of ships shown in Table 8.1 are presumably worked out on the same basis and those figures will be used in the calculations since Gilman's figures are provided only as a reasonable guide.

In the case of normal congestion, both tramp and liner operator charge at least for the time that their ships spend in the queue, and the penalty costs paid by the port authorities to waiting vessels are equal to the actual costs incurred by these vessels. However, surcharges are charged in the case of abnormal congestion (excessive waiting time). The surcharges are expressed normally as a percentage of the freight rate. The range of surcharges reported in 1975 (see Bennanthan and Walters 1979) was from 5 to 10 percent in Bombay to 130 percent in Tripoli and Latakia where over 90 ships were waiting for a berth and where the average delay was 40 days. Typically, surcharges are applied after abnormal congestion has been experienced and then only after warnings and notifications.

Column 4 of Table 8.1 (capital cost per berth) was supplied by the Port Authority and it includes quay, surfaced open area, storage area covered and open, quay cranes, mobile cranes, fork lift trucks and rail mounted and mobile gantry cranes for handling containers.

For general cargo and container berths the capital costs shown in Table 8.1 were given for 3 berths (for general cargo, capital costs for 3 berths was given as 24,000,000 and hence it would be 8,000,000 per berth, while for 3 container berths it was given as 69,000,000 and hence it would be 23,000,000 per berth) while for the rest of the berth types it was given as per berth.

Capital costs for berths vary from country to country and even in the same country depending on the location of the ports. Factors such as engineering costs to meet land and water requirements, construction work, geotechnical surveys and explorations, dredging, width and depth of the approach channels, lay-bys, breakwaters and locked basins, etc. plus the number of cranes, size of storage area covered, and open also vary from country to country depending on weather conditions and depth of the dredged channel which also influence the capital costs. For example, the capital costs for 4 container berths in Dammam, Saudi Arabia, was 1012 million Saudi Riyals (£240 million), SR 850 million for construction and SR 162 million for equipment[1], that is, the capital cost per container berth is £60 million (I.D. 21.6 million at the present rate of exchange).

For Mina Zayed in Abu Dhabi, construction costs were not given for the container berth, but the costs for the storage area and cranes were given as Dhs 8 million for storage and Dhs 37 for the container cranes, a total of Dhs 45 million (£10.3 million). They also provide the construction cost for a general cargo berth and a bulk cargo berth, each at Dhs 20 million[2] (£4.6 million).

The construction costs for the following ports was obtained from (Parsons, Brown and Newton 1983) for which they acted as consulting engineers.

Aqaba Port - Jordan

Bulk berth - construction cost £13 million*
General cargo/container berth - construction cost £15 million***

Croyton Jetty - River Thames

One berth for tankers - construction cost £1.35 million**

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1 United Nations Conference on Trade and Development, 1981

2 Seaport Authority - Mina Zayed - Emirate of Abu Dhabi, 1983

Nigg Bay Jetty - Cromarty Firth, Scotland

One berth for oil tankers - construction cost £11 million

Tarahan Jetty - Indonesia

Coal export berth - construction cost £3.5 million****

* excluding mechanical and electrical work
** excluding mechanical work
*** includes storage area and transit sheds
**** excluding mechanical and electrical work

Column 5 of Table 8.1 (maintenance and operation costs), were estimated by the Port Authority in Iraq at 1.5 percent of the capital cost while for Mina Zayed, Abu Dhabi they are estimated at ½ percent of the capital cost. This cost includes labour and staff costs, maintenance costs for the equipment, and fuel costs. Again these costs vary from country to country depending whether the port is labour intensive or capital intensive. In fact maintenance and operation costs might vary over the years for the same port. For example, maintenance costs might increase with time due to the fact that more maintenance is required as the equipment gets older and more breakdowns are likely to happen. No estimates could be obtained for the operation and maintenance costs with time, but even if they go up to 1.75 or 2 percent they should have no effect on the analysis since those costs are so small compared with the capital costs, if they go up by a much higher percentage, which is very unlikely, they could be easily adjusted.

Given the cost of a ship at sea, the cost in port/day and the handling rate in tons per day, the total cost/ton can be worked out (see Gilman 1977).

If C_s is the cost at sea/thousand miles/ton, and D is the port-to-port distance in thousand miles, then the total cost at sea for a round trip is $C_s \times D$.

If C_p is the cost in port/day, and H is the handling rate in tons/day, then the total port cost is $2C_p/H$ since each ton is handled twice.

Hence the round trip cost/ton, $C = C_sD + 2C_p/H$

To compare the total cost/ton say, for general cargo and containers, assume the following:-

General Cargo	Container
C_s = I.D. 1	C_s = 1.2
D = 6	D = 6
C_p = I.D. 1500 (see Table 8.1)	C_p = 2500 (see Table 8.1)
H = 822 (300,000/(365 x 24)	H = 1370 (500,000/(365 x 24)
Total cost/ton:	
$= 1 \times 6 + \frac{2 \times 1500}{822}$	$= 1.2 \times 6 + \frac{2 \times 2500}{1370}$
= 6 + 3.64 = 9.64 I.D.	= 7.2 + 3.64 = 10.84 I.D.

On dense routes where the cargo base is large enough not to impose a constraint on the choice of ship, and where service is frequent enough for changes in frequency to have little effect on the costs of users (shippers), the optimal ship for the route, defined as the ship that carries cargo of a given composition at the lowest total cost per cargo ton (see also Jansson and Shneerson 1982), could be worked out. In considering costs per ton of cargo (Gilman 1977) assumes that ships are carrying a full load in each direction and that cargo has the same stowage ratio on each ship of 2.85 cubic metres per weight ton.

Based on the above assumptions, two ships can be compared in order to determine the type and size of ship resulting in lower costs/ton.

In Section 8.2, a routing policy will be developed, in Section 8.5 the basic appraisal model (minimum cost point) will be developed and it will be extended to determine the optimal berthing capacity in Section 8.4.

8.2 Routing Policy

It was mentioned in Chapter 6 of this study that the berthing capacity for the general cargo traffic at Basra port cannot be increased because there is no room for expansion, and it will therefore be limited to 15 berths at any future time period. Due to this limitation, the optimal number of the general cargo ships arriving at Basra port for the periods 1985, 1990, 1995 and 2000 has to be determined so that the rest of the ships can be routed to Um Qasr port, where the berthing capacity can be increased to accomodate the growing demand.

Um Qasr port can be looked at as an extension to Basra port as far as general cargo ships are concerned. If for example 1000 ships were to arrive per year and 500 ships can be serviced at Basra, the other 500 ships will be serviced at Um Qasr; if 300 ships can be serviced at Basra, then the other 700 ships will be serviced at Um Qasr where some congestion will be created and new berths may have to be constructed to accomodate the spill over created by Basra.

The ships serviced at both ports will create some congestion, in addition to the congestion at Um Qasr, new berths may have to be constructed to reduce congestion. Therefore the congestion costs at both ports (waiting costs) plus the capital costs at Um Qasr (due to construction of new berths) will all be added together for different numbers of ships being serviced at each port, and the minimum value indicates that X number of ships serviced at Um Qasr together with Y number of ships serviced at Basra results in an optimal routing policy.

Before proceeding with the routing policy, a model has to be provided whereby the optimal number of berths can be determined for a particular demand in traffic which will be dealt with in Section 8.3.

Alternatively a different policy can be worked out which should lead approximately to the same results. Since the port authority earns revenues for services rendered to ships, the revenues received and waiting costs paid as penalties due to congestion can be plotted against the number of ships arriving per year, and the optimal number of ships that can be serviced at Basra port can be determined by locating the points on the curves where they are farthest apart. The maximum distance between the two curves indicates the point of maximum profits made by servicing a certain number of ships, if the number serviced is less or more, the profits are reduced indicating that the port is underutilised or over utilised as will be seen next.

The waiting costs of the general cargo ships serviced at Basra port is shown in Table 8.2, where the average waiting time per ship multiplied by the number of ships arriving per year multiplied by the waiting cost per ship per day results in the total waiting cost per year for that particular number of ships. As to the revenues (port tariffs) comprising cargo dues, anchorage dues, tug services ... etc., they average approximately 30105 I.D per general cargo ship.

Plotting the waiting costs shown in Table 8.2 and the revenues against the different number of ships arriving per year, as shown in Figures 8.1 to 8.4 for the periods 1985 to 2000 respectively, the number of ships that can be serviced in 1985 are approximately 670, in 1990 approximately 650, in 1995 approximately 560 and in 2000 approximately 550, all indicated by an arrow on the figures which is the maximum distance between the two curves.

Notice in this model that the revenue lines may go up or down depending on the port tariffs which could be increased or lowered. In both cases, the number of ships that can be serviced by the port does not change significantly. Figure 8.1 is reproduced in Figure 8.5 where different port tariffs (the broken lines in Figure 8.5) have been used, the upper line representing 37,500 I.D and the lower one representing 23,750 I.D per ship which is a significant change in port tariffs (25 per cent increase and over 21 per cent decrease), yet the number of ships resulting in the maximum profit remains the same at 670 ships. The reason for this is that the waiting cost curve is almost flat to start with up to a certain point, beyond which it turns upwards rapidly.

In Iraq it does not matter how many ships are serviced at each port as far as the revenues are concerned, because all ports belong to one

TABLE 8.2 WAITING COSTS FOR THE GENERAL CARGO SHIPS AT BASRA PORT, MOST LIKELY FORECASTS

	SHIPS	EXTRA BERTHS	W.C./S/D	A.W.T.(HR)	T.W.C./Y
1985	550	-	1500	10.28	353,375
	600	-	1500	11.79	442,125
	630	-	1500	15.68	617,400
	650	-	1500	16.42	667,062
	670	-	1500	23.87	999,556
	700	-	1500	79.93	3,496,937
	750	-	1500	403.28	18,903,750
	798	-	1500	1204.81	60,089,898
1990	500	-	1500	10.79	337,187
	550	-	1500	19.72	677,875
	600	-	1500	21.17	793,875
	650	-	1500	31.78	1,291,062
	675	-	1500	60.83	2,566,265
	700	-	1500	151.42	6,624,625
	750	-	1500	730.30	34,232,812
1995	500	-	1500	12.76	398,750
	520	-	1500	17.50	568,750
	560	-	1500	25.24	883,400
	580	-	1500	32.03	1,161,087
	600	-	1500	36.59	1,372,125
	650	-	1500	215.29	8,746,156
	700	-	1500	1169.95	51,185,312
2000	500	-	1500	15.25	476,562
	550	-	1500	24.26	833,937
	600	-	1500	33.53	1,257,375
	650	-	1500	180.39	7,328,343
	700	-	1500	884.19	38,683,312

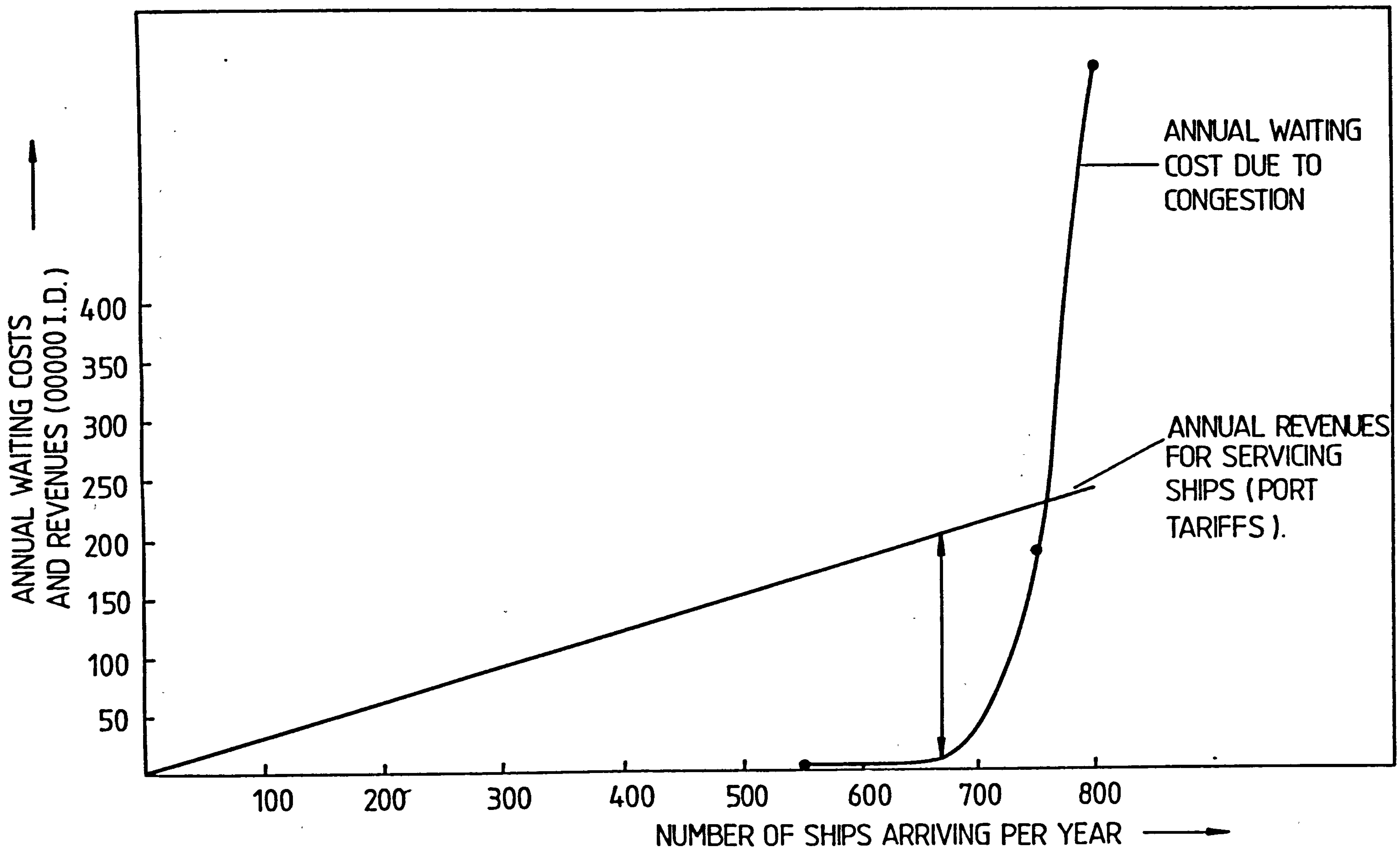

FIGURE 8-1 ANNUAL WAITING COSTS AND REVENUES V. NUMBER OF SHIPS ARRIVING PER YEAR, BASRA PORT, MLF, GENERAL CARGO 1985

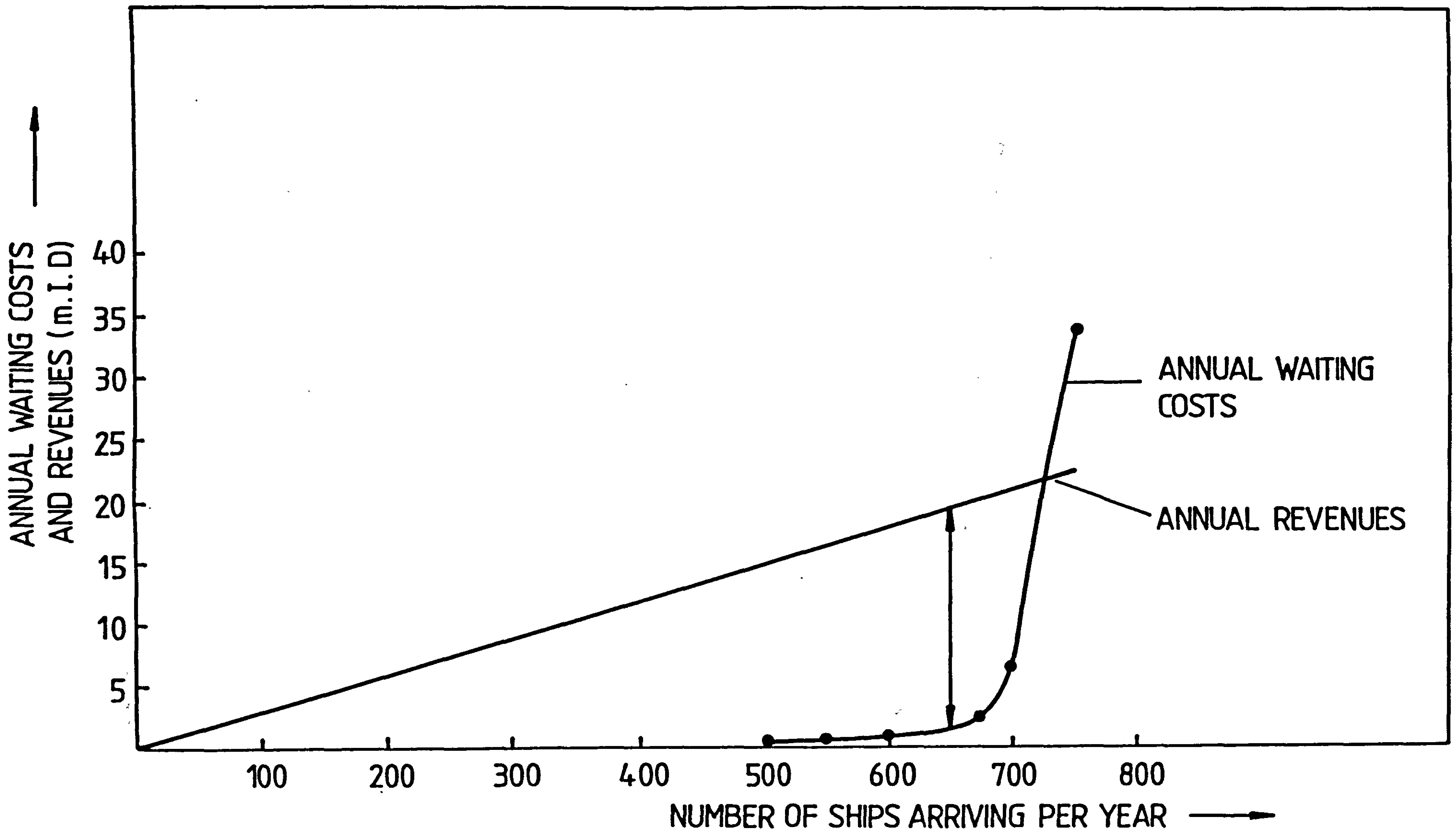

FIGURE 8-2 ANNUAL WAITING COSTS AND REVENUES V. NUMBER OF SHIPS ARRIVING PER YEAR BASRA PORT, MLF, G.C. 1990

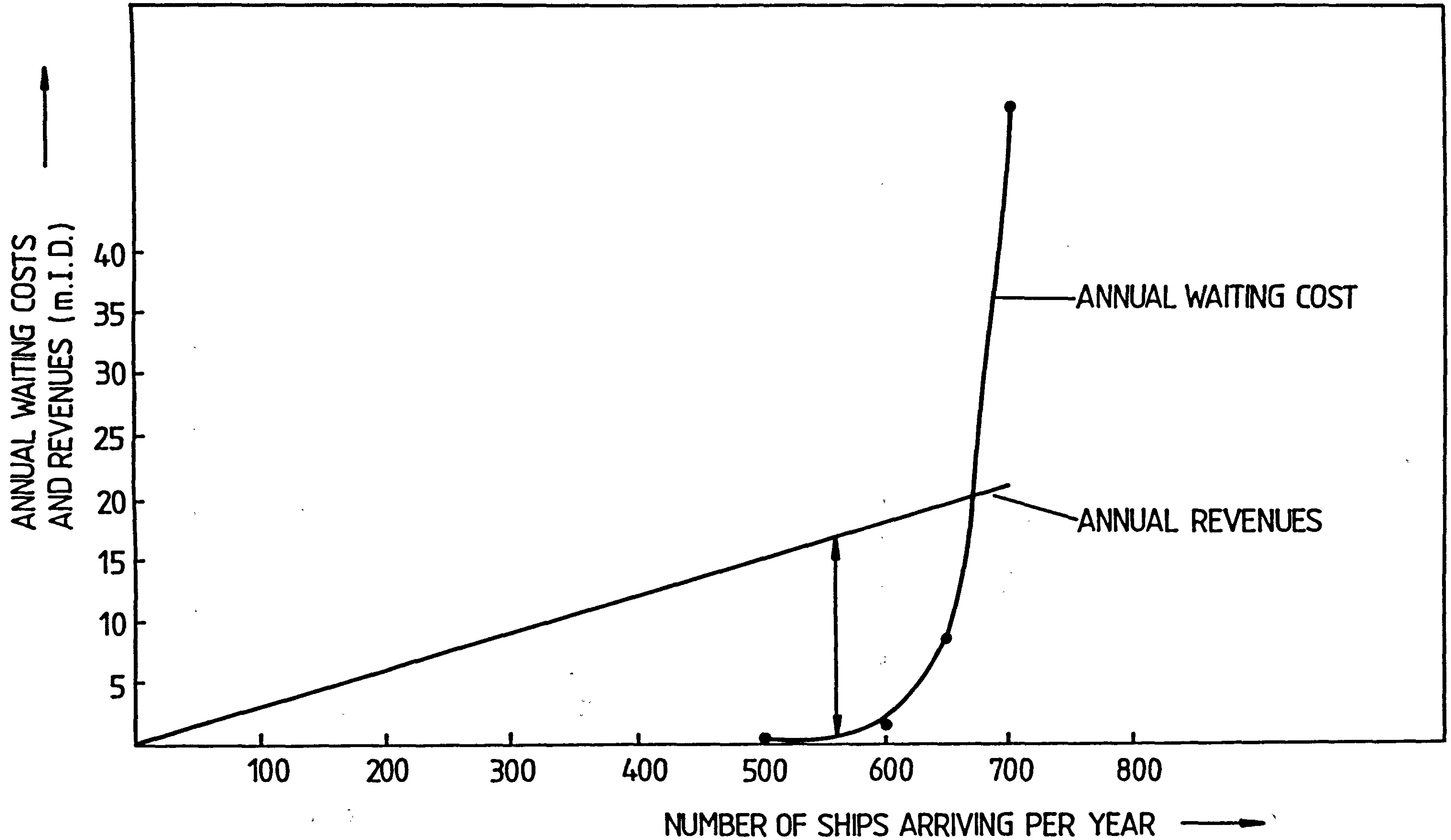

FIG 8-3 ANNUAL WAITING COSTS AND REVENUES V. NUMBER OF SHIPS ARRIVING PER YEAR.
BASRA PORT, MLF, G.C. 1995

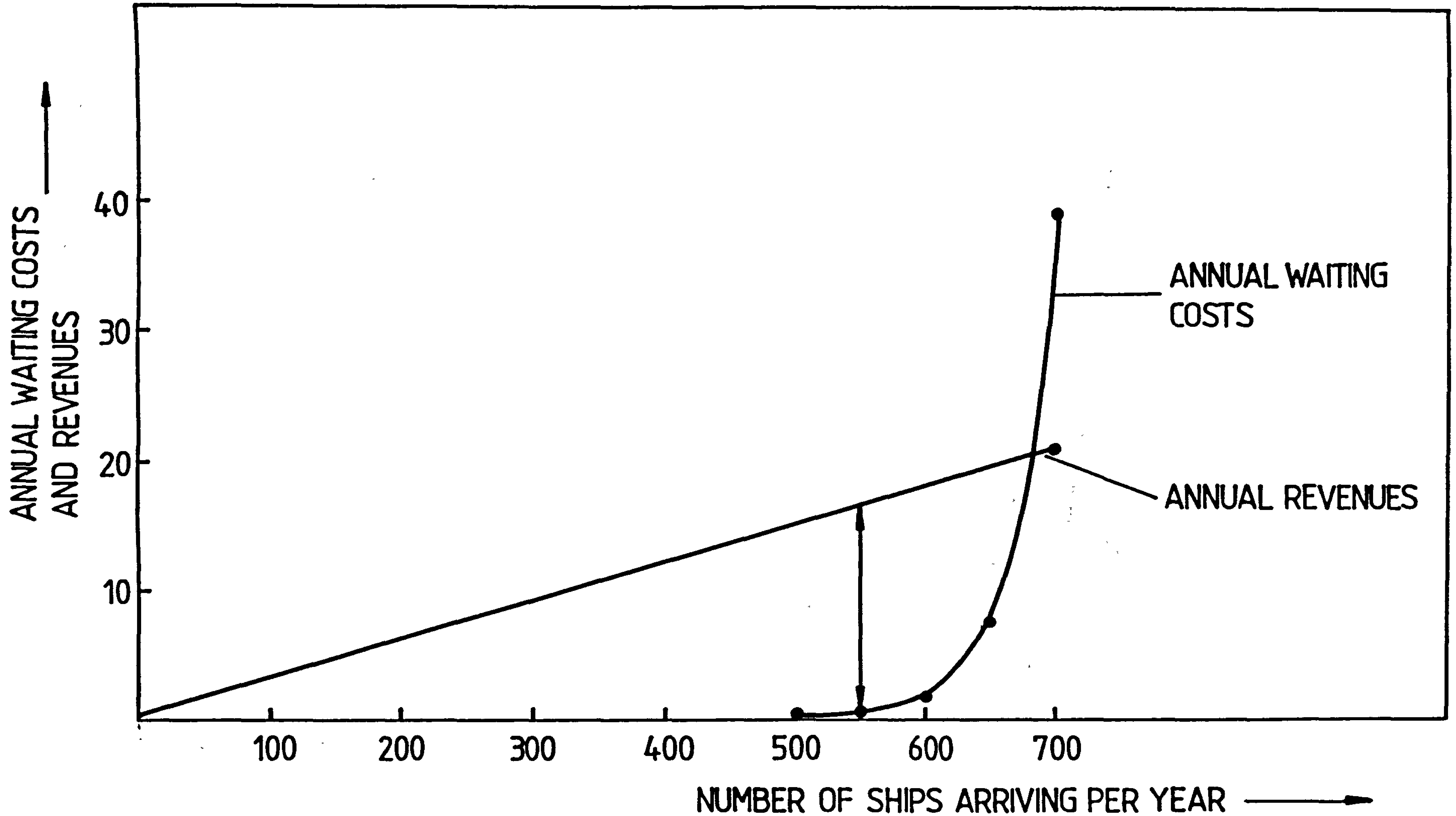

FIGURE 8 - 4 ANNUAL WAITING COSTS AND REVENUES V. NUMBER OF SHIPS ARRIVING PER YEAR, BASRA PORT, MLF, G.C. 2000

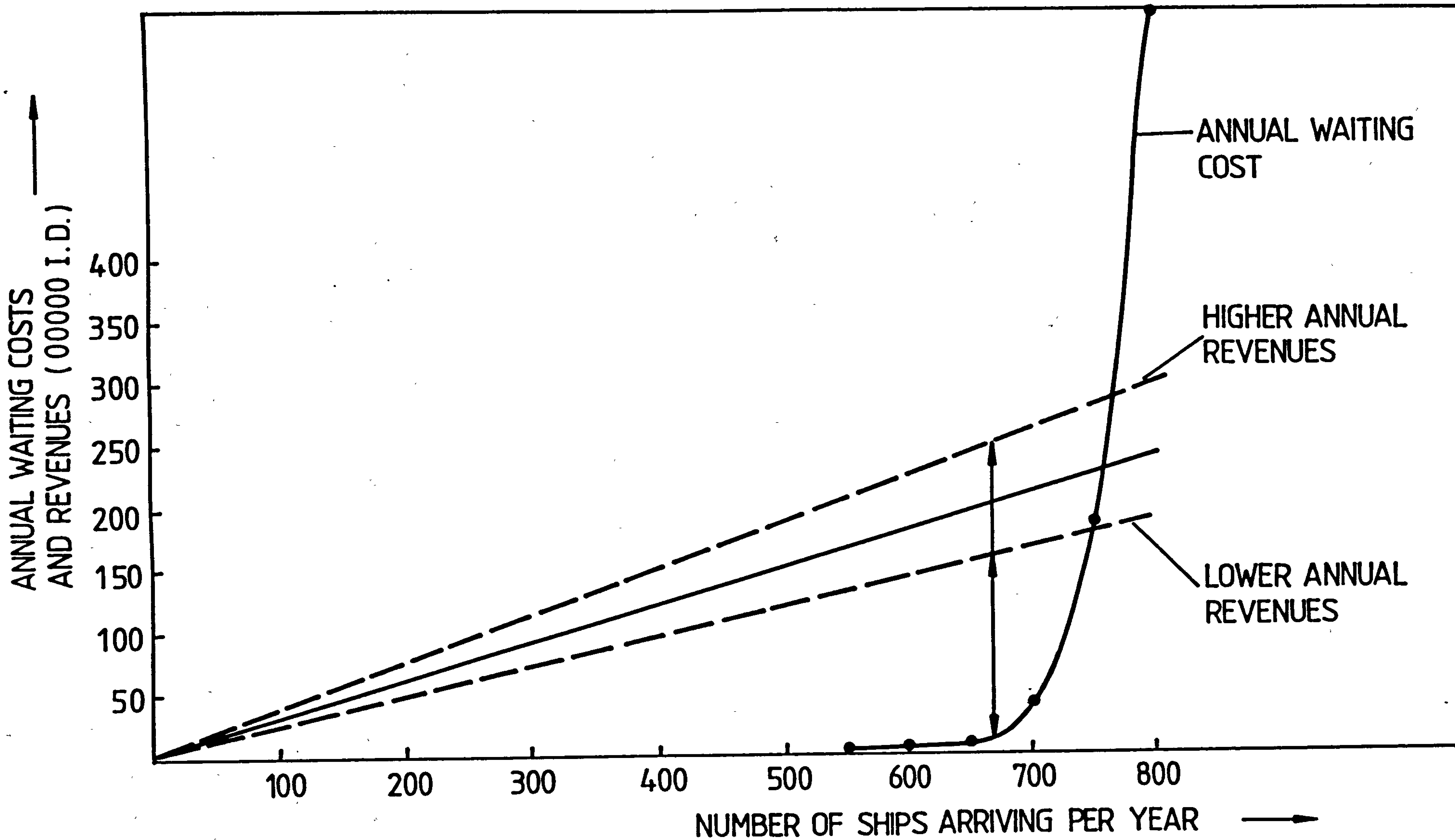

FIGURE 8-5 ANNUAL COSTS AND REVENUES V. NUMBER OF SHIPS ARRIVING PER YEAR, BASRA PORT MLF 1985

authority and are government owned. For example, if 1000 ships were to arrive per year, 200 are serviced at Basra and 800 at Um Qasr or 800 serviced at Basra and 200 at Um Qasr, the revenues will be the same in both cases, 1000 x 30105 = 30,105,000 I.D, but the costs incurred due to congestion will be different.

8.3 Minimum Cost Point Model

In this section an investment model resulting in the optimal number of berths for the years simulated (1985, 1990, 1995 and 2000) will be constructed and it will be extended in Section 8.4 to result in the optimal number of berths required at any future time period within the planning horizon.

The model is shown in Figure 8.6, where the capital costs, waiting costs and total costs (capital and waiting costs) are plotted against the number of new berths. In Chapter 7 of this study it was shown that the higher the number of berths servicing a certain amount of cargo carried by a certain number of ships, the lower the congestion (average waiting time per ship) and therefore the lower the waiting costs paid in penalties. This is shown by the waiting cost curve in Figure 8.6. On the other hand, the higher the number of berths constructed, the higher the capital cost. This is shown by the capital cost curve in Figure 8.6.

The total cost curve is obtained by adding the capital costs and waiting costs for different port configurations and the lowest point on this curve, C_0 represents the minimum total cost resulting in the optimal number of extra berths, B_0, that should be constructed.

The above model is now used to determined the optimum number of berths for different cargo types at all three ports and the most likely forecasts are considered first. Since the general cargo berths at Basra port are constant, the optimum number of ships that can be serviced there will be determined. As mentioned earlier in Section 8.2 the congestion costs at Basra and Um Qasr ports together with the

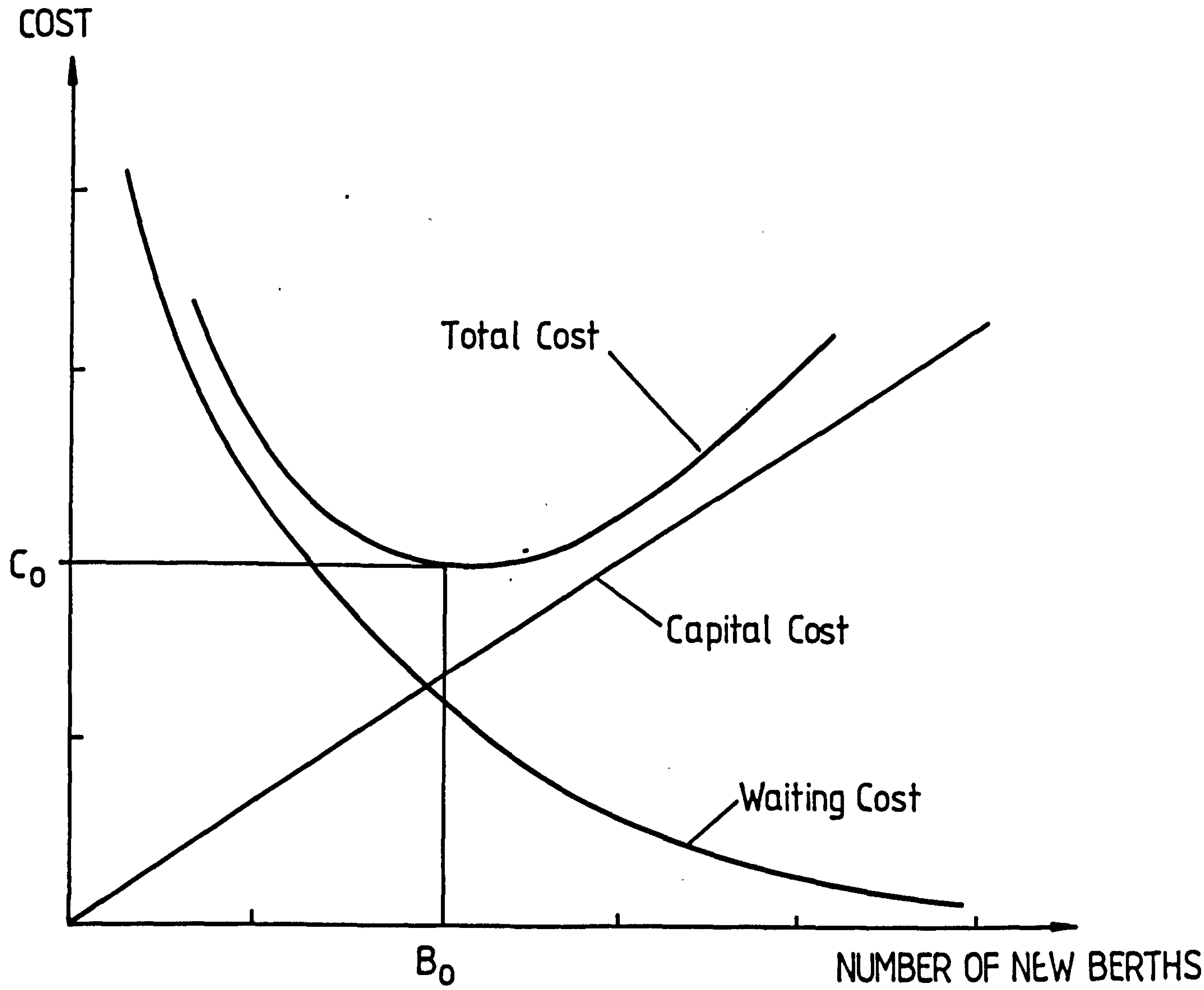

FIGURE 8·6 MINIMUM COST POINT MODEL

TABLE 8.3 TOTAL COSTS FOR GENERAL CARGO TRAFFIC AT UM QASR PORT, MOST LIKELY FORECASTS

	SHIPS	EXTRA BERTHS	W.C./S/D	A.W.T.(HR)	T.W.C./Y	BERTHS C.C/1Y	TOTAL COST
1985	201	0	1500	177.83	2,233,989	0	2,233,989
	201	1	1500	26.70	335,418	830,618	1,166,036
	201	2	1500	12.27	154,141	1,661,236	1,815,377
	201	3	1500	7.55	94,846	2,491,854	2,586,700
1990	532	5	1500	114.32	3,801,140	4,153,090	7,954,230
	532	6	1500	28.41	944,632	4,983,708	5,928,340
	532	7	1500	15.78	524,685	5,814,326	6,339,011
	532	8	1500	11.20	372,732	6,644,944	7,017,676
	532	9	1500	8.70	289,275	7,475,562	7,764,837
1995	1215	13	1500	236.07	16,598,671	10,798,034	27,396,705
	1215	14	1500	62.69	4,407,890	11,628,652	16,036,542
	1215	15	1500	38.20	2,685,937	12,459,270	15,145,207
	1215	16	1500	25.41	1,786,640	13,289,888	15,076,520
	1215	17	1500	17.74	1,247,343	14,120,506	15,367,849
	1215	18	1500	13.57	954,140	14,951,124	15,905,264
	1215	19	1500	10.62	746,718	15,781,742	16,528,460
2000	2426	22	1500	358.79	54,401,533	18,273,596	72,675,129
	2426	23	1500	133.80	20,287,425	19,104,214	39,391,639
	2426	24	1500	45.12	8,205,945	19,934,832	28,140,777
	2426	25	1500	27.06	4,102,972	20,765,450	24,868,422
	2426	26	1500	19.31	2,927,878	21,596,068	24,523,946
	2426	27	1500	14.98	2,271,342	22,426,686	24,698,028
	2426	28	1500	12.46	1,889,247	23,257,304	25,146,551
	2426	29	1500	10.64	1,613,290	24,087,922	25,701,212

TABLE 8.4 TOTAL COSTS FOR GENERAL CARGO TRAFFIC AT UM QASR PORT, MOST LIKELY FORECASTS

	SHIPS	EXTRA BERTHS	W.C./S/D	A.W.T.(HR)	T.W.C./Y	BERTHS C.C/1Y	TOTAL COST
1985	221	0	1500	836.27	11,550,979	0	11,550,979
	221	1	1500	120.07	1,658,466	830,618	2,489,084
	221	2	1500	51.55	712,034	1,661,236	2,373,270
	221	3	1500	21.64	298,902	2,491,854	2,790,756
	221	4	1500	9.77	134,948	3,322,472	3,457,420
1990	582	5	1500	1327.89	48,301,998	4,153,090	52,455,080
	582	6	1500	263.06	9,568,807	4,983,708	14,522,515
	582	7	1500	55.74	2,027,542	5,814,326	7,841,868
	582	8	1500	29.50	1,073,062	6,644,944	7,718,006
	582	9	1500	16.96	616,920	7,475,562	8,092,482
1995	1255	13	1500	367.50	28,825,781	10,798,034	39,623,815
	1255	14	1500	70.09	5,497,684	11,628,652	17,126,336
	1255	15	1500	39.87	3,127,303	12,459,270	15,586,573
	1255	16	1500	23.65	1,855,046	13,289,888	15,144,934
	1255	17	1500	16.83	1,320,103	14,120,506	15,440,609
	1255	18	1500	13.32	1,044,787	14,951,124	15,995,991
	1255	19	1500	11.24	881,637	15,781,742	16,663,379
2000	2476	23	1500	254.19	39,335,902	19,104,214	58,440,116
	2476	24	1500	57.83	8,949,192	19,934,832	28,884,024
	2476	25	1500	23.76	3,676,860	20,765,450	24,442,310
	2476	26	1500	18.30	2,831,925	21,596,068	24,427,993
	2476	27	1500	14.56	2,253,160	22,426,686	24,679,846
	2476	28	1500	11.82	1,892,145	23,257,304	25,086,449
	2476	29	1500	10.08	1,559,880	24,087,922	25,647,802
	2476	30	1500	8.88	1,374,180	24,918,540	26,292,720

TABLE 8.5 TOTAL COSTS FOR GENERAL CARGO TRAFFIC AT UM QASR PORT, MOST LIKELY FORECASTS

	SHIPS	EXTRA BERTHS	W.C./S/D	A.W.T.(HR)	T.W.C./Y	BERTHS C.C/1Y	TOTAL COST
1985	171	0	1500	65.47	699,710	0	699,710
	171	1	1500	17.90	191,306	830,618	1,021,924
	171	2	1500	7.97	85,179	1,661,236	1,746,415
	171	3	1500	5.71	61,025	2,491,854	2,552,879
1990	482	5	1500	62.25	2,679,687	4,153,090	6,832,777
	482	6	1500	19.10	835,625	4,983,708	5,819,333
	482	7	1500	9.81	443,187	5,814,326	6,257,513
1995	1165	13	1500	45.75	3,331,171	10,798,034	14,129,205
	1165	14	1500	26.13	1,902,590	11,628,652	13,531,242
	1165	15	1500	17.51	1,274,946	12,459,270	13,734,216
	1165	16	1500	12.07	878,846	13,289,888	14,168,734
	1165	17	1500	9.06	659,681	14,120,506	14,780,187
	1165	18	1500	7.37	536,628	14,951,124	15,487,752
	1165	19	1500	6.42	454,350	15,781,742	16,236,092
2000	2376	22	1500	62.69	9,309,465	18,273,596	27,583,061
	2376	23	1500	23.87	3,544,695	19,104,214	22,648,909
	2376	24	1500	18.72	2,779,920	19,934,832	22,714,752
	2376	25	1500	14.94	2,218,590	20,765,450	22,984,040
	2376	26	1500	12.30	1,826,550	21,596,068	23,422,618
	2376	27	1500	10.42	1,547,370	22,426,686	23,974,056
	2376	28	1500	9.20	1,366,200	23,257,304	24,623,504
	2376	29	1500	8.29	1,231,065	24,087,922	25,318,987

capital costs at Um Qasr will be added together for different numbers of ships arriving at each port to find the minimum total value.

Tables 8.3 to 8.5 show that Um Qasr port has been simulated for 201 general cargo ships (670 ships arriving at Basra port), 221 (650 at Basra), and 171 (700 at Basra) for the period 1985 and for different port configurations (different number of berths), the same was done for the periods 1990, 1995 and 2000 as shown in the tables. For 1985 congestion costs, capital costs and total costs were plotted against the extra number of berths as shown in Figure 8.7.

Figure 8.7 shows that the optimum number of berths that should be constructed in 1985 (general cargo) is 1 extra berth at a total cost of 1,166,036 I.D.[1] if 201 ships (670 at Basra) were to be serviced at Um Qasr; 2 extra berths at a total cost of 2,373,270 I.D. if 221 ships (650 at Basra); and no extra berths need to be constructed if 171 ships (700 at Basra) at a cost of 699,710 I.D (just the congestion cost at Um Qasr).

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[1] The total cost of 1,166,036 is obtained as follows:-
When 1 extra berth is constructed, congestion cost = 201 x 1500 x 26.70/24 = 335,418 I.D (see Table 8.3).

The port authority estimates the berth life time at 30 years, after which time it is considered to become obsolete and a discount rate of 8 per cent is used (see Section 4.4 of Chapter 4). Using Table B (Merrett and Sykes, 1971), 11.2578 is used to obtain the annual construction cost at 8 per cent discount rate for 30 years. Annual construction cost = 8000000/11.2578 = 710,618 I.D. Maintenance and operation cost = 0.015 x 8,000,000 = 120,000. Capital cost = 710,618 + 120,000 =830,618 I.D.

Total cost = 830,618 + 335,418 = 1,166,036 I.D.

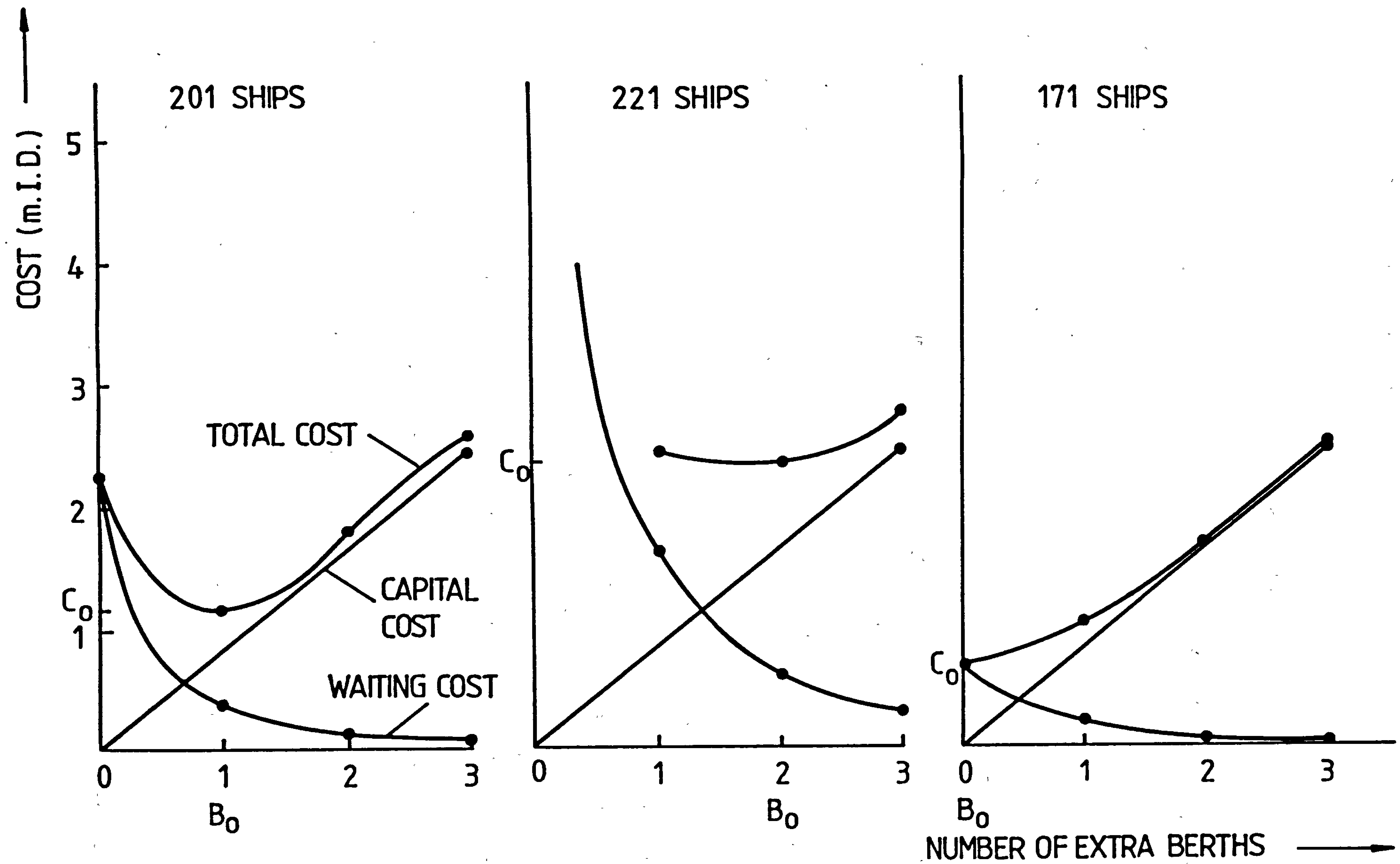

FIGURE 8-7 UM QASR PORT 1985, MLF, COST V. NUMBER OF EXTRA BERTHS, GENERAL CARGO

Adding the total costs at Um Qasr to the congestion costs at Basra, we get 1,166,036 + 999,556 (congestion at Basra for 670 ships, see Table 8.2) = 2,165,592 I.D

2,373,270 + 667,062 (congestion at Basra for 650 ships, see Table 8.2) = 3,040,332 I.D

699,710 + 3,496,937 (congestion at Basra for 700 ships, see Table 8.2) = 4,196,647 I.D

The minimum total cost at both ports is 2,165,592 I.D when 201 ships are diverted to be served at Um Qasr and 670 ships to be served at Basra which leads to the same result obtained in Section 8.2.

Originally there are 4 general cargo berths at Um Qasr, a new berth is constructed to make the number of berths required 5 in 1985.

The same procedure is adopted for the years 1990, 1995 and 2000, (where similar graphs to those shown in Figure 8.7 can be drawn) and the results obtained from Tables 8.3 to 8.5. For 1990, when 650 ships are served at Basra and 532 diverted to be served at Um Qasr, the minimum total cost at Um Qasr port is 5,928,340 I.D for an extra 6 berths. When 600 ships are served at Basra and 582 at Um Qasr, the cost is 7,718,006 I.D for an extra 8 new berths. When 700 ships are served at Basra and 482 diverted to be served at Um Qasr, the cost is 5,819,333 I.D for an extra 6 new berths as shown in Tables 8.3 to 8.5 respectively.

Adding those costs to the congestion costs at Basra we get:-

5,928,340 + 1,291,062 (congestion at Basra for 650 ships, see Table 8.2) = 7,219,402 I.D

7,718,006 + 793,875 (congestion at Basra for 600 ships, see Table 8.2) = 8,511,881 I.D

5,819,333 + 6,624,625 (congestion at Basra for 700 ships, see Table 8.2) = 12,443,958 I.D

The minimum total cost at both ports is 7,219,402 I.D when 650 ships are served at Basra and 532 at Um Qasr again leading to the same results obtained in Section 8.2.

In 1985 the number of berths was 5, and 6 more have to be constructed to make the number 11 by 1990.

For 1995

600 (Basra); 1215 (Um Qasr); the cost is 15,076,520; 16 extra berths

560 (Basra); 1255 (Um Qasr); the cost is 15,144,937; 16 extra berths

650 (Basra); 1165 (Um Qasr); the cost is 13,531,242; 14 extra berths

Adding the above costs to those at Basra we get:-

15,076,520 + 1,372,125 (congestion cost at Basra, see Table 8.2)
= 16,448,645 I.D

15,144,934 + 833,400 (congestion cost at Basra, see Table 8.2)
= 16,028,334 I.D

13,531,242 + 8,746,156 (congestion cost at Basra, see Table 8.2)
= 22,277,398

For 2000

600 (Basra); 2426 (Um Qasr); cost 24,523,946; 26 extra berths

550 (Basra); 2476 (Um Qasr); cost 24,427,993; 26 extra berths

650 (Basra); 2376 (Um Qasr); cost 22,648,909; 23 extra berths

Adding the above costs to those at Basra we get:-

24,523,946 + 1,257,375 (see Table 8.2)
= 25,781,321 I.D

24,427,993 + 833,937 (see Table 8.2)
= 25,261,930 I.D

22,684,909 + 7,328,343 (see Table 8.2)
= 29,977,252 I.D

The minimum total cost at both ports is 25,261,930 I.D when 550 ships are served at Basra and 2476 at Um Qasr.

The number of ships served at each port, the total costs and the number of berths that should be made available at Um Qasr for the years 1985 to 2000 are summarised in Table 8.6.

Table 8.6 NUMBER OF SHIPS SERVED AT EACH PORT, TOTAL COST AND OPTIMUM NUMBER OF GENERAL CARGO BERTHS AT UM QASR

	SHIPS SERVED AT		TOTAL COST (I.D)	NUMBER OF BERTHS AT UM QASR
	BASRA	UM QASR		
1985	670	201	2,165,592	5
1990	650	532	7,219,402	11
1995	560	1255	16,028,334	27
2000	550	2476	25,261,930	53

Basra port has been simulated for different port configurations for 74 grain ships arriving in 1985 (original number of berths in 1979 was 2), the total costs for 1985 are shown in Table 8.7. From this table it can be seen that the minimum total cost is 3,287,437 with 2 extra berths required, making the total number of berths required by 1985 four berths. Since demand for this particular cargo is decreasing over the years up to the year 2000, it is clear that 4 berths

TABLE 8.7 <u>TOTAL COSTS FOR GRAIN TRAFFIC AT BASRA PORT, MOST LIKELY FORECASTS</u>

	SHIPS	EXTRA BERTHS	W.C./S/D	A.W.T.(HR)	T.W.C./Y	BERTHS C.C/1Y	TOTAL COST
1985	74	0	1100	11,496.02	38,990,667	0	38,990,667
	74	1	1100	3,771.13	12,790,415	1,245,927	14,036,342
	74	2	1100	234.57	795,583	2,491,854	3,287,437
	74	3	1100	92.32	313,118	3,737,781	4,050,899
	74	4	1100	19.93	67,595	4,983,708	5,051,303
	74	5	1100	6.04	20,485	6,229,635	6,250,120
1990	59	0	1100	95.19	257,409	0	257,409
	59	1	1100	24.72	66,847	1,245,927	1,312,774

should be enough to cater for the rest of the years. It might be argued here, that since demand is decreasing, then perhaps 1 extra berth might be sufficient in 1985 although high congestion costs will be incurred (14,036,324, see Table 8.7), which might be balanced by the idle cost in future. It can be seen that the total cost of 2 extra berths in 1985 results in a cost of 3,287,437, while if one extra berth is provided the cost is 14,036,343, implying that a saving of 10,748,905 I.D is made if 2 berths are constructed. In addition to this saving, the waiting costs for 1990 - 2000 will be higher if 1 extra berth is constructed and less if 2 extra berths are constructed (see Tables 6.14 to 6.17) adding more to the 14,036,342 cost incurred in 1985, and therefore, 4 berths should be in operation for the periods 1985 - 2000 for the grain cargo.

Oil cargo was simulated for the original number of berths (1 in 1979) and for 1, 2, 3 ... extra berths in 1985. The total cost for the periods 1985, 1990, 1995 and 2000 for different port configurations is shown in Table 8.8. It can be seen from this table that no extra berths need to be constructed for the periods 1985 and 1990, and one extra berth has to be constructed in 1995, in other words, the existing berth is sufficient to meet the 1985 and 1990 demand and an extra berth has to be constructed in 1995 to meet the demand for the periods 1995 and 2000.

Sugar cargo was simulated for the original number of berths (1 in 1979, originally used for urea, but will be used for sugar since urea traffic will be serviced in Khor Al Zubair port from 1985 onwards)[1] and for 1, 2, 3 ... extra berths in 1985. The total cost for the periods 1985 1990, 1995 and 2000 for different port configurations is shown in Table 8.9. It can be seen from this table that only one extra berth need to be constructed in 1985 to meet the demand for the periods 1985 - 2000.

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[1] General Organisation for Ports

TABLE 8.8 TOTAL COSTS FOR OIL TRAFFIC AT BASRA PORT, MOST LIKELY FORECASTS

	SHIPS	EXTRA BERTHS	W.C./S/D	A.W.T.(HR)	T.W.C./Y	BERTHS C.C/1Y	TOTAL COST
1985	21	0	950	69.60	57,855	0	57,855
	21	1	950	13.78	11,454	1,142,100	1,153,554
	21	2	950	11.52	9,576	2,284,200	2,293,776
	21	3	950	6.35	5,278	3,426,300	3,431,578
1990	19	0	1000	359.05	284,248	0	284,248
	19	1	1000	102.13	80,853	1,142,100	1,225,953
	19	2	1000	12.74	10,086	2,284,200	2,294,286
1995	20	0	1100	2998.87	2,748,964	0	2,748,964
	20	1	1100	111.29	102,016	1,142,100	1,244,116
	20	2	1100	15.27	13,997	2,284,200	2,298,197
2000	28	0	1100	137.03	175,855	0	175,855
	28	1	1100	35.75	45,879	1,142,100	1,187,979

TABLE 8.9 TOTAL COST FOR SUGAR TRAFFIC AT BASRA PORT, MOST LIKELY FORECASTS

	SHIPS	EXTRA BERTHS	W.C./S/D	A.W.T.(HR)	T.W.C./Y	BERTHS C.C/1Y	TOTAL COST
1985	42	0	950	2312.57	3,844,647	0	3,844,687
	42	1	950	56.04	93,166	1,245,927	1,339,093
	42	2	950	10.96	18,221	2,491,854	2,510,075
	42	3	950	10.18	16,924	3,737,781	3,754,705
1990	33	0	1000	62.59	86,061	0	86,061
	33	1	1000	18.93	26,028	1,245,927	1,271,955
	33	2	1000	11.50	15,812	2,491,854	2,507,666
1995	30	0	1100	130.74	179,767	0	179,767
	30	1	1100	20.04	27,555	1,245,927	1,273,482
2000	35	0	1100	208.85	335,030	0	335,030
	35	1	1100	33.20	53,258	1,245,927	1,299,185

For Khor Al Zubair port, the number of new berths that has to be constructed for fertiliser, sulphur, urea and phosphate traffic is shown in Tables 8.10 to 8.13 respectively. For the fertiliser traffic one extra berth has to be constructed in 1985 and another in 1990; for sulphur traffic, three new berths have to be constructed in 1985; for urea traffic, two new berths have to be constructed in 1985 and an extra berth has to be constructed in 1990; and for phosphate traffic, one new berth has to be constructed in 1985 and two extra berths have to be constructed in 1990.

In Um Qasr port, the number of extra berths that have to be constructed for the container traffic for the periods 1985, 1990, 1995 and 2000 is shown in Table 8.14. It can be seen from this table, that 3 extra berths have to be constructed in 1985 making a total of 4 berths; 3 extra berths have to be constructed in 1990 making a total of 7 berths; 5 extra berths have to be constructed in 1995 making a total of 12 berths; and 6 extra berths have to be constructed in 2000 making a total of 18 berths.

Since the difference between the three forecasts for the grain, oil, sugar, fertiliser, sulphur, urea and phosphate cargo is small (see Tables 5.21 to 5.23) only the most likely forecasts were simulated and evaluated, while for the general and container cargo separate simulations were made and the evaluations follow next.

For the optimistic forecasts, since the amount of cargo to be handled for both general and container traffic is more than 1.5 times that of the most likely forecasts (see Tables 5.21 and 5.22), the simulations were based on the berths working continuously, that is, 24 hours a day (no shift constraint). While the operation and maintenance cost was 1.5 per cent of the construction cost for a 12 hour day, it is assumed to be 4.125 per cent of the construction cost for a 24 hour day.

Take for example, a general cargo berth where the construction cost is 8,000,000 I.D at 1.5 per cent (for a 12 hour day), the maintenance

TABLE 8.10 TOTAL COSTS FOR FERTILISER TRAFFIC AT KHOR AL ZUBAIR PORT, MOST LIKELY FORECASTS

	SHIPS	EXTRA BERTHS	W.C./S/D	A.W.T.(HR)	T.W.C./Y	BERTHS C.C/1Y	TOTAL COST
1985	44	0	950	745.26	1,297,994	0	1,297,994
	44	1	950	12.17	21,196	1,349,755	1,370,951
1990	50	0	1100	5518.31	12,646,127	0	12,646,127
	50	1	1100	434.14	994,904	1,349,755	2,344,659
	50	2	1100	43.79	100,352	2,699,510	2,799,862

TABLE 8.11 TOTAL COST FOR SULPHUR TRAFFIC AT KHOR AL ZUBAIR PORT, MOST LIKELY FORECASTS

	SHIPS	EXTRA BERTHS	W.C./S/D	A.W.T.(HR)	T.W.C./Y	BERTHS C.C/1Y	TOTAL COST
1985	69	2	1100	1902.34	6,016,150	2,699,510	8,715,660
	69	3	1100	47.22	149,333	4,049,265	4,198,598
1990	75	0	1100	171.02	587,881	0	587,881
	75	1	1100	40.09	137,809	1,349,755	1,487,564
	75	2	1100	10.80	37,125	2,699,510	2,736,635

TABLE 8.12 TOTAL COSTS FOR UREA TRAFFIC AT KHOR AL ZUBAIR, MOST LIKELY FORECASTS

	SHIPS	EXTRA BERTHS	W.C./S/D	A.W.T.(HR)	T.W.C./Y	BERTHS C.C/1Y	TOTAL COST
1985	75	2	950	162.27	481,739	2,699,510	3,181,249
	75	3	950	28.05	83,273	4,049,265	4,132,538
1990	50	0	1100	1303.34	2,986,820	0	2,986,820
	50	1	1100	38.13	87,381	1,349,755	1,437,136
	50	2	1100	11.11	25,460	2,699,510	2,724,970

TABLE 8.13 TOTAL COSTS FOR PHOSPHATE TRAFFIC AT KHOR AL ZUBAIR PORT, MOST LIKELY FORECASTS

	SHIPS	EXTRA BERTHS	W.C./S/D	A.W.T.(HR)	T.W.C./Y	BERTHS C.C/1Y	TOTAL COST
1985	25	1	950	51.01	50,478	1,349,755	1,400,233
	25	2	950	6.33	6,264	2,699,510	2,705,774
1990	75	2	1100	450.11	1,547,253	2,699,510	4,246,763
	75	3	1100	75.67	260,115	4,049,265	4,309,380
	75	4	1100	32.37	111,271	5,399,020	5,510,291

TABLE 8.14 TOTAL COSTS FOR CONTAINER TRAFFIC AT UM QASR PORT, MOST LIKELY FORECASTS

	SHIPS	EXTRA BERTHS	W.C./S/D	A.W.T.(HR)	T.W.C./Y	BERTHS C.C/1Y	TOTAL COST
1985	597	2	2500	1297.99	80,718,753	4,776,056	85,494,809
	597	3	2500	24.56	1,527,325	7,164,084	8,691,409
	597	4	2500	11.01	684,684	9,552112	10,236,796
	597	5	2500	6.97	433,446	11,940,140	12,373,586
1990	912	2	2500	385.94	36,664,300	4,776,056	41,440,356
	912	3	2500	21.61	2,052,950	7,164,084	9,217,034
	912	4	2500	9.83	933,850	9,552,112	10,485,962
	912	5	2500	7.23	686,850	11,940,140	12,626,990
	912	6	2500	6.06	575,700	14,328,168	14,903,868
1995	1508	3	2500	366.20	57,523,916	7,164,084	64,688,000
	1508	4	2500	29.64	4,655,950	9,552,112	14,208,062
	1508	5	2500	13.49	2,119,054	11,940,140	14,059,194
	1508	6	2500	9.13	1,434,170	14,328,168	15,762,338
	1508	7	2500	6.97	1,094,870	16,716,196	17,811,066
2000	2504	4	2500	640.50	167,036,750	11,940,140	178,976,890
	2504	5	2500	43.57	11,364,508	14,328,168	25,692,676
	2504	6	2500	19.10	4,981,916	16,716,196	21,698,112
	2504	7	2500	12.18	3,176,950	19,104,224	22,281,174
	2504	8	2500	9.44	2,462,266	21,492,252	23,954,418
	2504	9	2500	8.00	2,086,666	23,880,280	25,966,946
	2504	10	2500	7.04	1,836,266	26,268,308	29,104,574

and operation costs are 0.015 x 8,000,000 = 120,000 I.D. Assuming that in the next 6 hours the pay is 1.5 that of the normal hours and in the last 6 hours the pay is double that of the normal hours, the operation and maintenance cost is 0.015/2 x 8,000,000 x 1.5 = 90,000 I.D for the next 6 hours and 0.015/2 x 8,000,000 x 2 = 120,000 I.D. for the last 6 hours. Adding the operation and maintenance cost for the first 12 hours (normal hours) plus the next 6 hours (1.5 the normal hours) plus the last 6 hours (double the normal hours) gives 120,000 + 90,000 + 120,000 = 330,000 I.D., and adding this figure to the annual cost of 8,000,000/11.2578 (710,618) gives 710,618 + 330,000 = 1,040,618 I.D capital cost per annum. The same is done to determine the capital cost per annum for containers (23,000, 000/11.2578 + 0.015 x 23,000,000 + 0.15 x 23,000,000 x 1.5 + 0.015 x 23,000,000) = 2,043,028 + 345,000 + 258,750 + 345,000 = 2,991,778 I.D.

Using the minimum cost point model to determine the number of extra berths that have to be constructed as was done previously, the results for the general cargo berths are shown in Table 8.15. It can be seen from this table, that no extra berths need to be constructed in 1985 leaving the total at 4 berths; 6 new berths have to be constructed in 1990 making a total of 10 berths; 15 extra berths have to be constructed in 1995 making a total of 25 berths; and 27 extra berths have to be constructed in 2000 making a total of 52 berths.

For container traffic, the number of extra berths that have to be constructed for the same periods is shown in Table 8.16. It can be seen from this table that 2 extra berths have to be constructed in 1985 making a total of 3 berths; 2 extra berths in 1990 making a total of 5 berths; 4 extra berths in 1995 making a total of 9 berths; and 6 extra berths in 2000 making a total of 15 berths.

Finally the pessimistic forecasts are considered and the results for general cargo and container cargo are shown in Tables 8.17 and 8.18 respectively.

For general cargo, no extra berths are required in 1985; 1 extra berth is required in 1990; 9 extra berths in 1995 and 11 extra berths in 2000.

TABLE 8.15 TOTAL COSTS FOR GENERAL CARGO TRAFFIC AT UM QASR PORT, OPTIMISTIC FORECASTS

	SHIPS	EXTRA BERTHS	W.C./S/D	A.W.T.(HR)	T.W.C./Y	BERTHS C.C/IY	TOTAL COST
1985	348	0	1500	18.80	408,900	0	408,900
	348	1	1500	6.12	133,110	1,040,618	1,173,728
	348	2	1500	2.87	62,422	2,081,236	2,143,658
	348	3	1500	2.17	47,195	3,121,854	3,169,049
	348	4	1500	2.02	43,935	4,162,472	4,206,407
1990	932	5	1500	69.74	4,062,355	5,203,090	9,265,445
	932	6	1500	23.53	1,370,622	6,243,708	7,614,330
	932	7	1500	10.98	639,585	7,284,326	7,923,911
	932	8	1500	6.11	355,907	8,324,944	8,680,851
	932	9	1500	3.90	227,175	9,365,562	9,592,737
1995	2199	12	1500	185.62	25,511,148	12,487,416	37,998,564
	2199	13	1500	67.72	9,307,267	13,528,034	22,835,301
	2199	14	1500	22.01	3,024,999	14,568,652	17,593,651
	2199	15	1500	12.36	1,698,727	15,609,270	17,307,997
	2199	16	1500	7.66	1,052,771	16,649,888	17,702,659
2000	4701	23	1500	315.61	92,730,163	23,934,214	116,664,377
	4701	24	1500	145,53	42,788,533	24,974,832	67,763,365
	4701	25	1500	47.97	14,094,185	26,015,450	40,109,635
	4701	26	1500	19.49	5,726,405	27,056,068	32,782,473
	4701	27	1500	11.16	3,278,947	28,096,686	31,375,633
	4801	28	1500	8.06	2,368,128	29,137,304	31,505,432

TABLE 8.16 TOTAL COSTS FOR CONTAINER TRAFFIC AT UM QASR PORT, OPTIMISTIC FORECASTS

	SHIPS	EXTRA BERTH	W.C./S/D	A.W.T.(HR)	T.W.C./Y	BERTHS C.C/1Y	TOTAL COST
1985	709	1	2500	77.69	5,737,730	2,991,778	8,729,508
	709	2	2500	6.24	460,850	5,983,556	6,444,406
	709	3	2500	2.82	209,745	8,975,334	9,185,079
	709	4	2500	2.04	150,662	11,967,112	12,117,774
1990	1182	1	2500	37.11	4,569,168	2,991,778	7,560,946
	1182	2	2500	6.19	762,143	5,983,556	6,745,699
	1182	3	2500	2.93	360,756	8,975,334	9,336,090
	1182	4	2500	2.09	257,331	11,967,112	12,224,443
	1182	5	2500	1.83	225,318	14,958,890	15,184,208
1995	2216	2	2500	594.37	126,812,908	5,983,556	132,796,464
	2216	3	2500	21.25	4,905,208	8,975,334	13,880,542
	2216	4	2500	6.84	1,578,900	11,967,112	13,546,012
	2216	5	2500	3.86	891,016	14,958,890	15,849,906
	2216	6	2500	2.57	593,241	17,950,668	18,543,909
2000	4149	4	2500	662.25	286,216,172	11,967,112	298,183,284
	4149	5	2500	46.05	19,902,234	14,958,890	34,861,124
	4149	6	2500	8.62	3,725,456	17,950,668	32,676,124
	4149	7	2500	4.95	2,139,328	20,942,446	23,081,774
	4149	8	2500	3.33	1,439,184	23,934,224	25,373,408
	4149	9	2500	2.53	1,093,434	26,926,002	28,019,436

TABLE 8.17 TOTAL COSTS FOR GENERAL CARGO TRAFFIC AT UM QASR PORT, PESSIMISTIC FORECASTS

	SHIPS	EXTRA BERTHS	W.C./S/D	A.W.T.(HR)	T.W.C./Y	BERTHS C.C/1Y	TOTAL COST
1985	73	0	1500	81.47	371,706	120,000	491,706
	73	0	1500	13.49	61,548	120,000	181,548
	73	0	1500	7.81	35,633	120,000	155,633
	73	1	1500	5.48	25,002	830,618	855,620
1990	233	1	1500	58.05	845,353	830,618	1,675,971
	233	2	1500	25.34	369,013	1,661,236	2,030,249
	233	3	1500	13.30	193,681	2,491,854	2,685,535
	233	4	1500	9.35	136,159	3,322,472	3,458,631
1995	626	8	1500	85,30	3,337,362	6,644,944	9,982,306
	626	9	1500	41.52	1,624,470	7,475,562	9,100,032
	626	10	1500	26.58	1,039,942	8,306,180	9,346,112
	626	11	1500	17.37	679,601	9,136,798	9,816,399
	626	12	1500	12.42	485,932	9,967,416	10,453,348
2000	1167	10	1500	62.27	4,541,818	8,306,180	12,847,998
	1167	11	1500	31.98	2,332,541	9,136,798	11,469,339
	1167	12	1500	20.95	1,528,040	9,967,416	11,495,456
	1167	13	1500	14.13	1,030,606	10,798,034	11,828,640
	1167	14	1500	10.78	786,266	11,628,652	12,414,918

TABLE 8.18 TOTAL COSTS FOR CONTAINER TRAFFIC AT UM QASR PORT, PESSIMISTIC FORECASTS

	SHIPS	EXTRA BERTHS	W.C./S/D	A.W.T.(HR)	T.W.C./Y	BERTHS C.C/1Y	TOTAL COST
1985	505	2	2500	63.42	3,336,156	4,776,056	8,112,212
	505	3	2500	11.58	609.156	7,164,084	7,773,240
	505	4	2500	7.20	378,750	9,552,112	9,930,86s
	505	5	2500	5.98	314,573	11,940,140	12,254,713
1990	707	1	2500	100.04	7,367,529	2,388,028	9,755,577
	707	2	2500	22.39	1,648,930	4,776,056	6,424,986
	707	3	2500	10.43	768,126	7,164,084	7,932,210
	707	4	2500	7.48	550,870	9,552,112	10,102,982
	707	5	2500	6.12	450,712	11,940,140	12,390,852
1995	1036	1	2500	306.53	33,079,695	2,388,028	35,467,723
	1036	2	2500	23.69	2,556,545	4,776,056	7,332,601
	1036	3	2500	11.41	1,231,329	7,164,084	8,395,413
	1036	4	2500	7.92	854,700	9,552,112	10,406,812
	1036	5	2500	6.49	700,379	11,940,140	12,640,519
	1036	6	2500	5.74	619,441	14,328,168	14,947,609
2000	1190	0	2500	358.80	44,476,250	0	44,476,250
	1190	1	2500	24.32	3,014,666	2,388,028	5,402,694
	1190	2	2500	11.66	1,445,354	4,776,056	6,221,410
	1190	3	2500	8.00	991,666	7,164,084	8,155,750
	1190	4	2500	6.49	804,489	9,552,112	10,356,601
	1190	5	2500	5.97	740,031	11,940,140	12,680,171

TABLE 8.19 NUMBER OF BERTHS MLF

	ORIG-INAL	1985		1990		1995		2000	
		EXTRA	TOTAL	E	T	E	T	E	T
BASRA PORT									
GRAIN	2	2	4	0	4	0	4	0	4
OIL	1	0	1	0	1	1	2	0	2
SUGAR	1	1	2	0	2	0	2	0	2
KHOR AL ZUBAIR PORT									
FERT.	1	1	2	1	3	0	3	0	3
SULP.	0	3	3	0	3	0	3	0	3
UREA	0	2	2	1	3	0	3	0	3
PHOS.	0	1	1	2	3	0	3	0	3
UM QASR PORT									
G.C	4	1	5	6	11	16	27	26	53
CONT.	1	3	4	3	7	5	12	6	18

TABLE 8.20 NUMBER OF BERTHS OPTIMISTIC FORECASTS

UM QASR PORT									
G.C	4	0	4	6	10	15	25	27	52
CONT.	1	2	3	2	5	4	9	6	15

TABLE 8.21 NUMBER OF BERTHS PESSIMISTIC FORECASTS

UM QASR PORT									
G.C	4	0	4	1	5	9	14	11	29
CONT.	1	3	4	2	6	2	8	1	9

The results for the original number of berths, the extra number of berths required for each class of cargo and the total number of berths, for the periods 1985, 1990, 1995 and 2000 for the most likely, optimistic and pessimistic forecasts are shown in Tables 8.19 to 8.21.

8.4 Extensions to the Minimum Cost Point Model

In the previous section, it was shown how the optimum number of berths required to cater for the demand of specific future years can be determined through the use of the minimum cost point model. Referring to Tables 8.19 to 8.21 and considering general cargo and container traffic, it can be seen that the extra number of berths that have to be constructed in each time period is high. Looking at the general cargo traffic for example, Table 8.19 shows that 5 berths are required by 1985; 11 in 1990; 27 in 1995 and 53 in 2000. Therefore 16 new berths have to be constructed between the period 1990 and 1995, and 26 new berths have to be constructed between the period 1995 and 2000, which illustrates that the optimum number of berths for the years 1996, 1997, 1998, 1999 has to be determined also, and not only at 5 years intervals, otherwise, in between the 5 years intervals very high congestion will be created when demand increases rapidly, if the optimum number of berths for the in between years is not determined.

As mentioned earlier in Section 4.4 of Chapter 4, when demand is increasing rapidly, as in the case of general and container cargo, the optimum number of berths has to be determined on a year by year basis to avoid the cost of high congestion. This implies that 16 sets of yearly forecasts, 16 sets of simulations, and 16 sets of evaluations have to be made for the years 1985 - 2000 for each class of cargo. This will lead to an immense, cumbersome, costly and time consuming amount of work, and the longer the planning horizon, the more immense the problem becomes. For this reason, the minimum cost point model will be further developed to result in the optimum number of berths required at any future time period using only 4 points in time instead of 16, and hence reducing the amount, time and cost by at least 75 per cent which is a very substantial reduction.

To illustrate how this can be achieved, consider the general and container traffic (most likely forecasts). Having determined the optimum number of berths for the years 1985, 1990, 1995 and 2000 (see Section 8.3), the number of ships arriving in those four periods is plotted against the time in years. Passing a smooth curve through those four points as shown in Figures 8.8 (general cargo) and 8.9 (containers), enables us to determine the number of ships arriving at any future year without having to do the separate forecasts. By projecting a vertical line for the year required to meet the curve and then projecting a horizontal line will determine the number of ships arriving in that particular year as shown in Figures 8.8 and 8.9.

Figure 8.8 shows that 800 ships arrive in 1992 and 1920 ships in 1998 for general cargo, and Figure 8.9 shows that 1115 ships arrive in 1992 and 2035 ships in 1998 for container cargo, and the number of ships arriving at any desired year can be determined from the figures in the same way.

Next the number of ships arriving for the years 1985, 1990, 1995 and 2000 is plotted against the optimum number of berths for the periods above (determined in Section 8.3) as shown in Figures 8.10 (general cargo) and 8.11 (containers). From those figures the optimum number of berths for any number of ships arriving, and hence for any year, can be determined.

Figure 8.10 shows that 800 ships (1992) require 17 berths and 1920 ships (1998) require 42 berths for the general cargo traffic, and Figure 8.11 shows that 1115 ships (1992) require 9 berths and 2035 ships (1998) require 16 berths for the container traffic.

In order to validate the above models, the forecasts for the years 1992 and 1998 for general and container cargo were worked out, simulated and then evaluated to determine the optimum number of berths required for those two periods.

Using the models developed in Chapter 5 of this study, the most likely forecasts for general and container cargo were worked out and shown

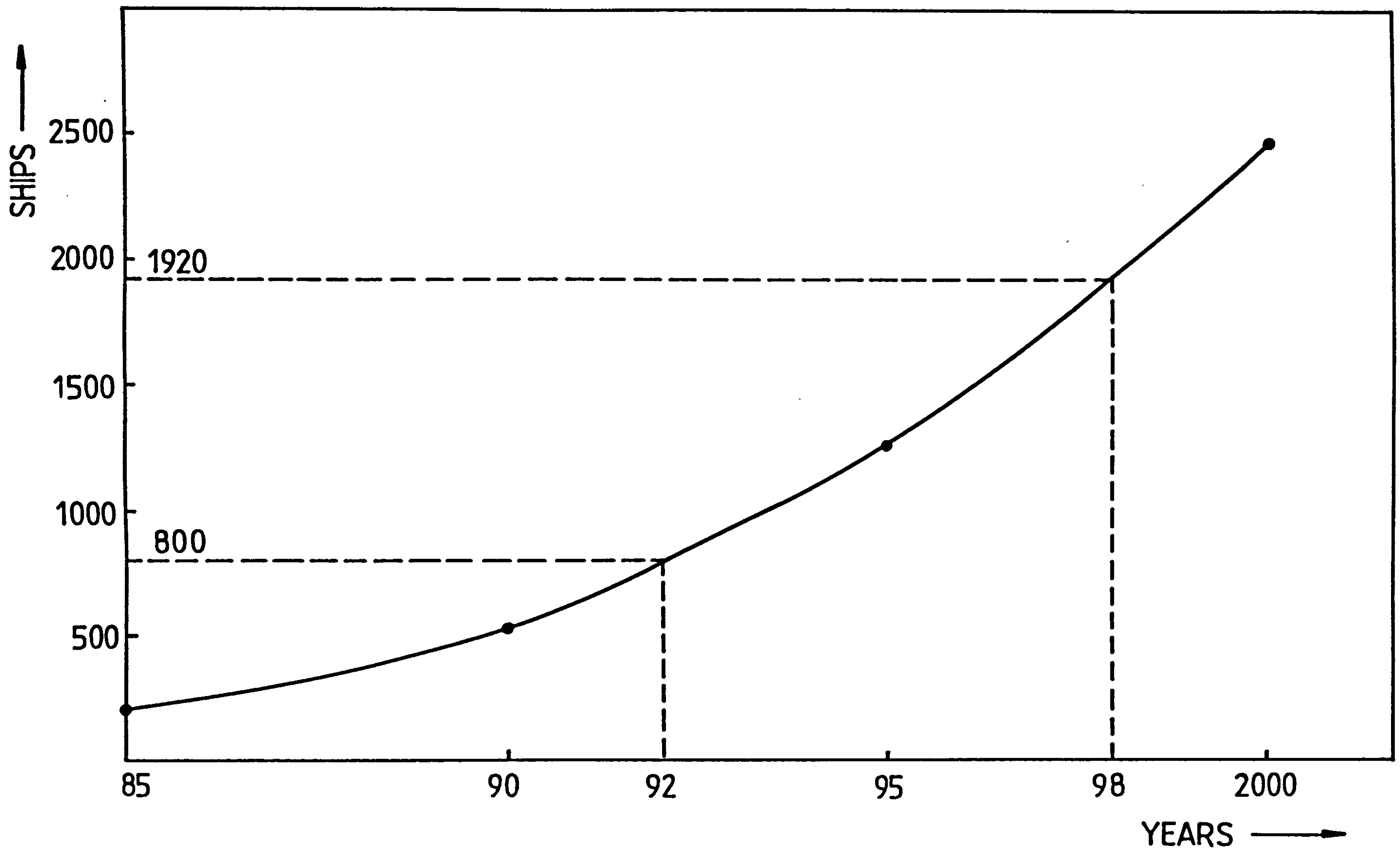

FIGURE 8-8 UM QASR PORT, MLF, GENERAL CARGO TRAFFIC, BERTHS OPERATE 12 HOURS, DEMAND (SHIPS) V. TIME (YEARS)

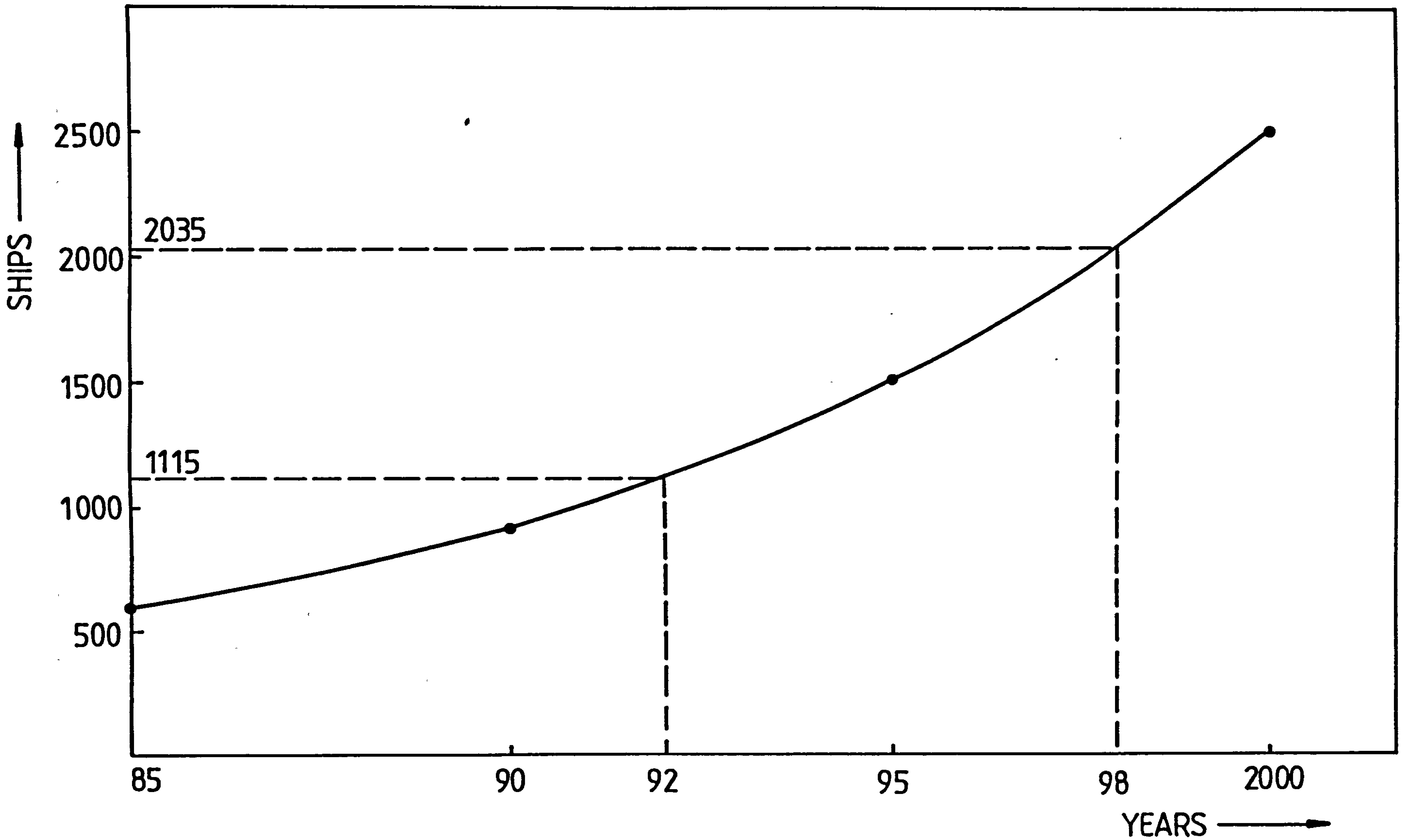

FIGURE 8-9 UM QASR PORT, MLF, CONTAINER TRAFFIC BERTHS OPERATE 12 HOURS, DEMAND (SHIPS) V. TIME (YEARS)

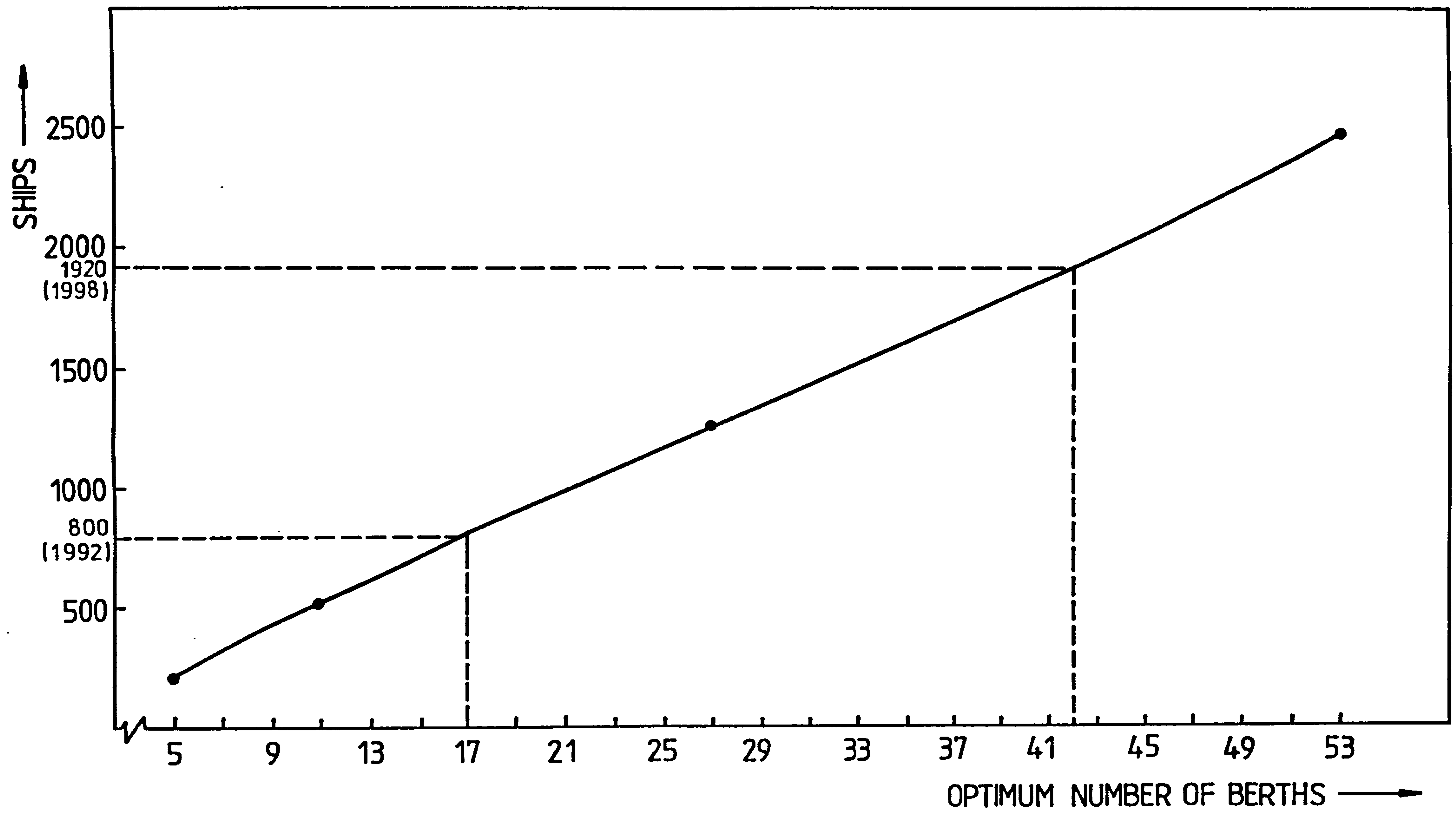

FIGURE 8-10 UM QASR PORT, MLF, GENERAL CARGO TRAFFIC, BERTHS OPERATE 12 HOURS, DEMAND (SHIPS) V. OPTIMUM NUMBER OF BERTHS

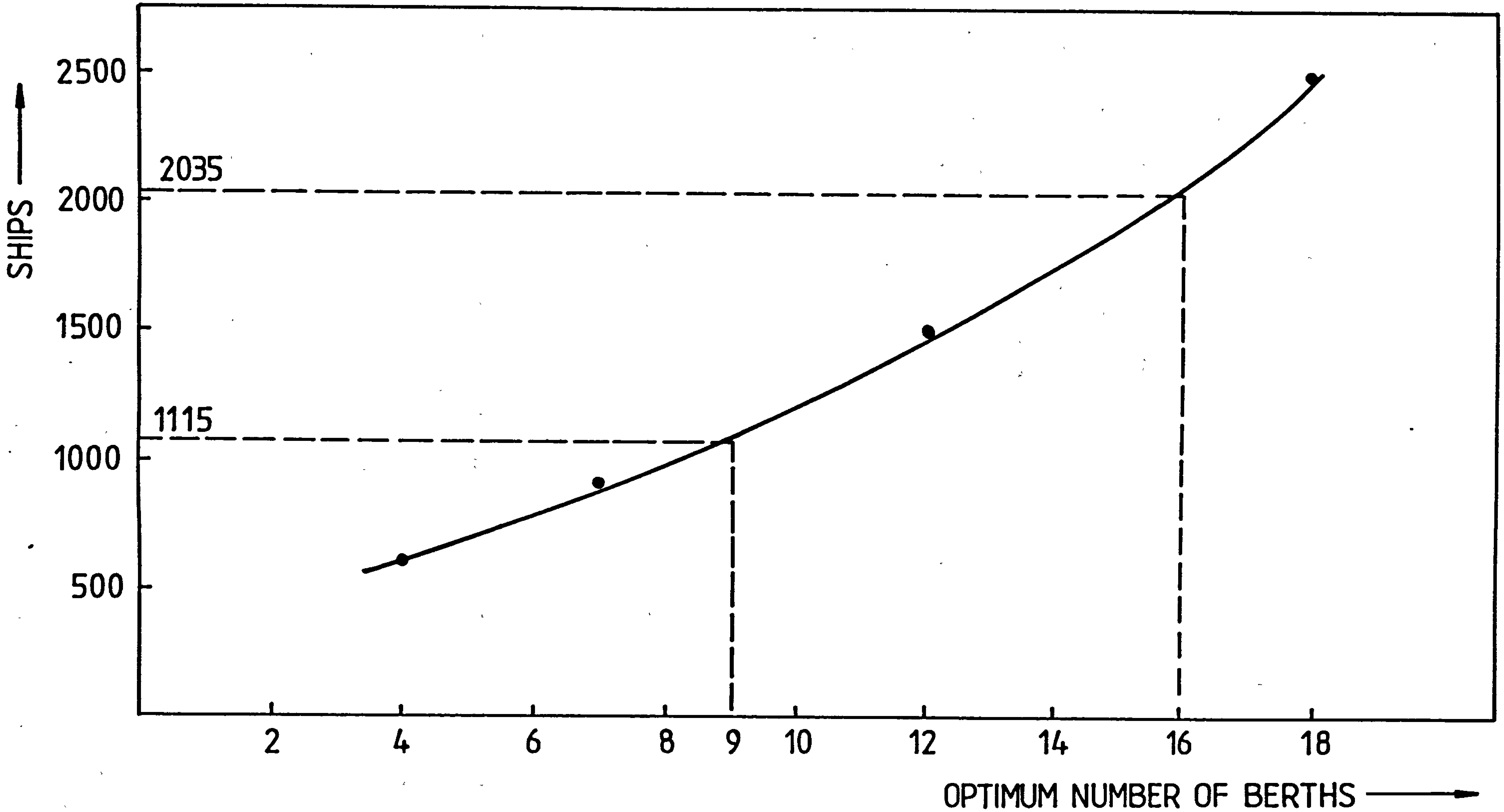

FIGURE 8-11 UM QASR PORT, MLF, CONTAINER TRAFFIC, BERTHS OPERATES 12 H/D, DEMAND (SHIPS) V. OPTIMUM NUMBER OF BERTHS

in Table 8.22. The number of ships arriving in 1992 and 1998 for the general cargo and container traffic obtained by using the forecasting models of Chapter 5 and by the models in Figures 8.8 and 8.9 are almost the same and therefore the latter model can be used to predict the number of ships for any future year without having to go into the trouble of making separate yearly forecasts.

The simulation results for the periods 1992 and 1998 for the general and container cargo are shown in Tables 8.23 and 8.24 and the simulation output in Appendix F.. Having obtained the average waiting time per ship for the two cargo classes, the minimum cost point model is used to determine the extra number of berths required for the years 1992 and 1998 and the evaluations are shown in Tables 8.25 and 8.26.

Table 8.25 (general cargo) shows that the extra number of berths required in 1992 is 6 at a minimum total cost of 6,420,858 I.D making a total of 17 berths, and 15 extra berths are required in 1998 at a minimum total cost of 15,406,134 I.D. making a total of 42 berths.

Comparing the number of berths obtained through simulation and evaluation with those obtained from Figure 8.10 (general cargo), the results are the same, 17 berths for 1992 and 42 berths for 1998.

Table 8.26 (containers) shows that the extra berths required in 1992 is 2 at a minimum total cost of 6,439,264 I.D. making a total of 9 berths and 4 extra berths in 1998 at a minimum total cost of 14,749,502 I.D. making a total of 16 berths, again giving the same results obtained from Figure 8.11. Hence the models in Figures 8.10 and 8.11 can be used to predict the optimum number of berths required at any future year without having to go into the trouble of making yearly simulations and evaluations.

Finally the number of ships against the year and the number of ships against the optimum number of berths for the optimistic and pessimistic forecasts of the general cargo and container traffic are shown in Figures 8.12 to 8.19. Notice in Figure 8.17 that 2 instead of 4 berths

TABLE 8.22 MOST LIKELY FORECASTS FOR GENERAL AND CONTAINERISED CARGO 1992, 1998

GENERAL CARGO MOST LIKELY FORECASTS		
ITEM	1992	1998
2. AUTOMOBILES	65,033	121,639
3. COAL	0	0
6. DRUGS & CHEMICALS	0	0
10. GUNNIES	41,035	19,989
11. IRON & STEEL	4,615,220	8,632,375
14. MACHINERY	62,691	117,259
21. TEA	45,545	55,662
22. TIMBER	739,854	1,383,834
23. OTHERS	2,428,159	4,541,663
TOTAL	7,997,537	14,872,421
less what is served at Basra	3,575,000	3,360,000
TOTAL at Um Qasr	4,422,532	11,512,421
divided by the average ship load	5,500	6,000
SHIPS ARRIVING	804	1,919
CONTAINER TRAFFIC MOST LIKELY FORECASTS		
ITEM	1992	1998
1. Alcohol ...	40,328	75,430
4. Cotton ...	28,779	38,566
6. Drugs ...	491,394	919,110
7. Electrical ...	98,872	184,932
8. Food	0	0
9. Glassware	28,771	39,670
13. Leather	0	0
14. Machinery	62,691	117,259
16. Paper	65,078	4,643
17. Paints	2,000	2,000
18. Refrigerators ...	99,711	186,501
23. Others	3,428,169	4,541,663
TOTAL	3,345,783	6,109,774
divided by the average ship load	3,000	3,000
SHIPS ARRIVING	1,115	2,037

TABLE 8.23 UM QASR PORT MLF 1992 B.O.12H/D

TYPE	Q.S	N.S.A	A.S.L	B.C	μ	σ	N.B.	A.W.T	% I.T	%I.T.B	A.S.T	M.Q.L	>24H	>120H	>240H
1. G.C	4,422,532	804	5500	300,000	161	36	15	315.52	0	0	165.85	57	ALL OVER 84H		
2. CONT.	3,441,902	1115	3087	500,000	54	9	7	729.25	0	0	59.55	130	ALL OVER 384H		
							16	50.19	113.44	7.09	166.06	20	408	139	-
							8	37.29	43.78	5.47	59.52	20	651	49	-
							17	28.60	220.10	12,94	165.95	16	264	15	-
							9	14,32	143.14	15.90	59.61	12	206	-	-
							18	18.46	326.42	18.13	165.96	15	185	4	-
							10	8.64	242.32	24.23	59.64	8	64	-	-
							19	13.01	428,65	22.56	166.16	13	133	-	-
							11	6.85	340.10	30.91	59.71	6	19	-	-
							20	9,51	530.15	26.50	166.09	11	84	-	-
							12	6.10	436.68	36.39	59.65	6	11	-	-

TABLE 8.24 UM QASR PORT MLF 1998 B.O. 12H/D

TYPE	Q.S .	N.S.A	A.S.L	B.C.	μ	σ	N.B	A.W.T	% I.T	%I.T/B	A.S.T	M.Q.L	>24H	>120H	>240H
1. G.C	11,514,421	1,919	6,000	300,000	175	40	39	168.65	0	0	180.06	75	ALL OVER 36H		
2. CONT.	6,241,433	2,037	3,064	500,000	54	9	13	673.30	0	0	59.55	271	ALL OVER 276H		
							40	67.22	61.91	1.54	180.16	52	1379	340	-
							14	101.09	11.10	0.79	59.49	81	1745	660	263
							41	37.74	160.51	3.91	180.15	41	974	86	-
							15	26.82	68.17	4.54	59.54	30	938	-	-
							42	24.57	270.07	6.43	180.22	35	642	13	-
							16	13.24	159.57	9.97	59.62	18	335	-	-
							43	18.75	391.91	9.11	180.28	29	495	-	-
							17	9.71	259.95	15.29	59.60	15	160	-	-
							44	14.54	499.78	11.35	180.19	22	386	-	-
							18	7.96	357.52	19.86	59.67	13	77	-	-
							45	11.46	604.98	13.44	180.15	17	272	-	-
							19	6.86	458.15	24.11	59.65	12	32	-	-

TABLE 8.25 TOTAL COSTS FOR GENERAL CARGO TRAFFIC AT UM QASR PORT, MOST LIKELY FORECASTS

	SHIPS	EXTRA BERTHS	W.C./S/D	A.W.T.(HR)	T.W.C./Y	BERTHS C.C/1Y	TOTAL COST
1992	804	4	1500	315,52	15,854,880	3,322,472	19,177,352
	804	5	1500	50.91	2,558,227	4,153,227	6,711,317
	804	6	1500	28.60	1,437,150	4,983,708	6,420,858
	804	7	1500	18.46	927,615	5,814,326	6,741,941
	804	8	1500	13.01	653,752	6,644,944	7,298,696
	804	9	1500	9.51	477,877	7,475,562	7,953,439
1998	1919	12	1500	168.65	20,227,459	9,967,416	30,194,875
	1919	13	1500	67.22	8,062,199	10,798,034	18,860,233
	1919	14	1500	37.74	4,526,441	11,628,652	16,155,093
	1919	15	1500	24.57	2,946,864	12,459,270	15,406,134
	1919	16	1500	18.75	2,248,828	13,289,888	15,538,716
	1919	17	1500	14.54	1,743,891	14,120,506	15,864,397
	1919	18	1500	11.46	1,374,483	14,951,124	16,325,607

TABLE 8.26 TOTAL COSTS FOR CONTAINER TRAFFIC AT UM QASR PORT, MOST LIKELY FORECASTS

	SHIPS	EXTRA BERTHS	W.C./S/D	A.W.T.(HR)	T.W.C./Y	BERTHS C.C/1Y	TOTAL COST
1992	1115	0	2500	729.25	84,699,349	0	84,699,349
	1115	1	2500	37.29	4,331,078	2,388,028	6,719,106
	1115	2	2500	14.32	1,663,208	4,776,056	6,439,264
	1115	3	2500	8.64	1,003,500	7,164,084	8,167,585
	1115	4	2500	6.85	795,599	9,552,112	10,347,711
	1115	5	2500	6.10	708,489	11,940,140	12,684,629
1998	2037	1	2500	673.30	142,865,844	4,776,056	147,641,899
	2037	2	2500	101.09	21,450,034	7,164,084	28,614,118
	2037	3	2500	26.82	5,690,869	9,552,112	15,242,981
	2037	4	2500	13.24	2,809,362	11,940,140	14,749,502
	2037	5	2500	9.71	2,060,340	14,328,168	16,388,508
	2037	6	2500	7.96	1,689,012	16,716,196	18,405,208
	2037	7	2500	6.86	1,455,606	19,104,224	20,559,830

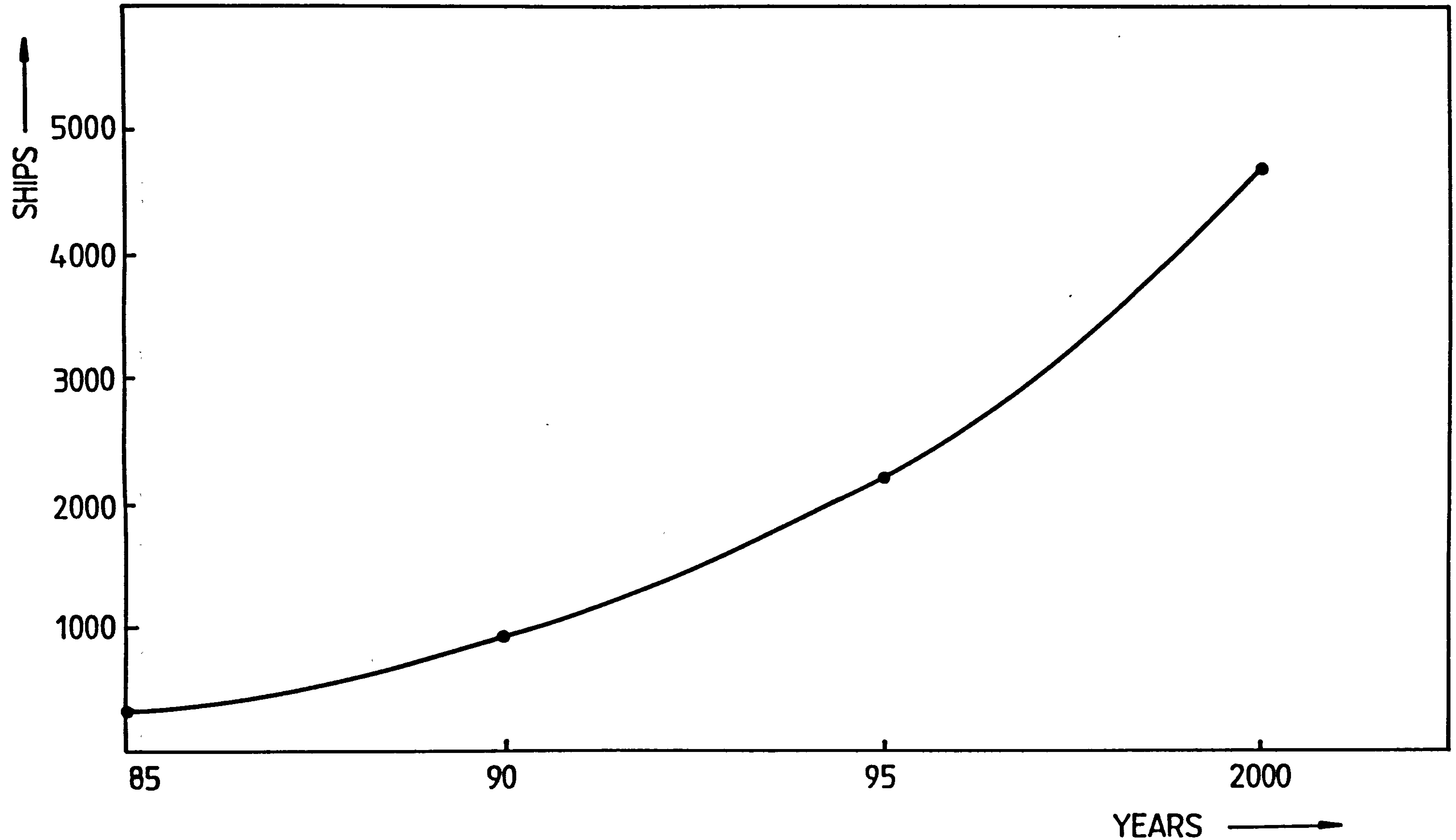

FIGURE 8-12 UM QASR, OPTIMISTIC FORECASTS, GENERAL CARGO TRAFFIC, BERTHS OPERATE 24 H, DEMAND (SHIPS) V. TIME (YEARS)

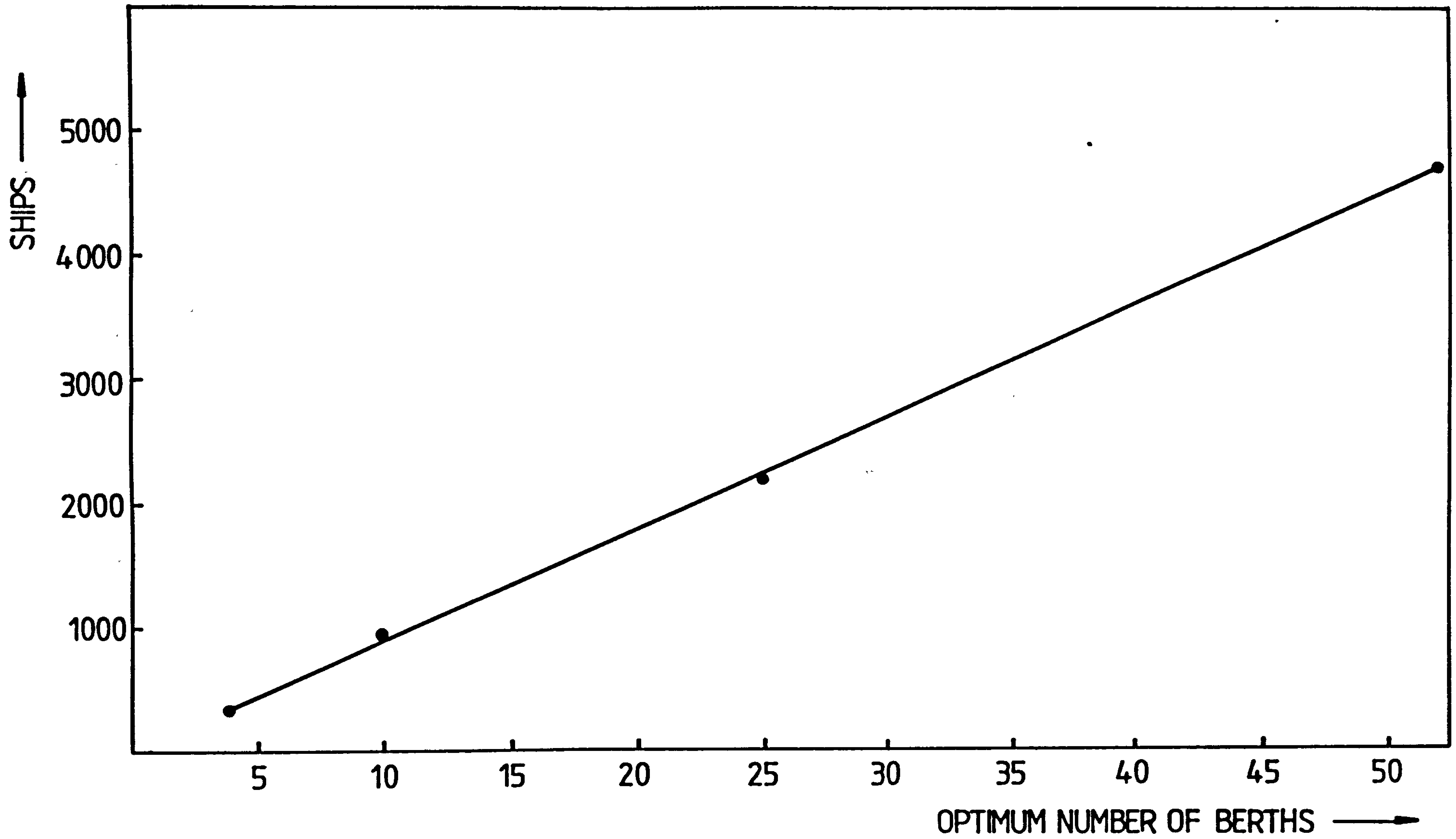

FIGURE 8-13 UM QASR PORT, OPTIMISTIC FORECASTS, GENERAL CARGO TRAFFIC, BERTHS OPERATE 24 H, DEMAND (SHIPS) V. OPTIMUM NUMBER OF BERTHS

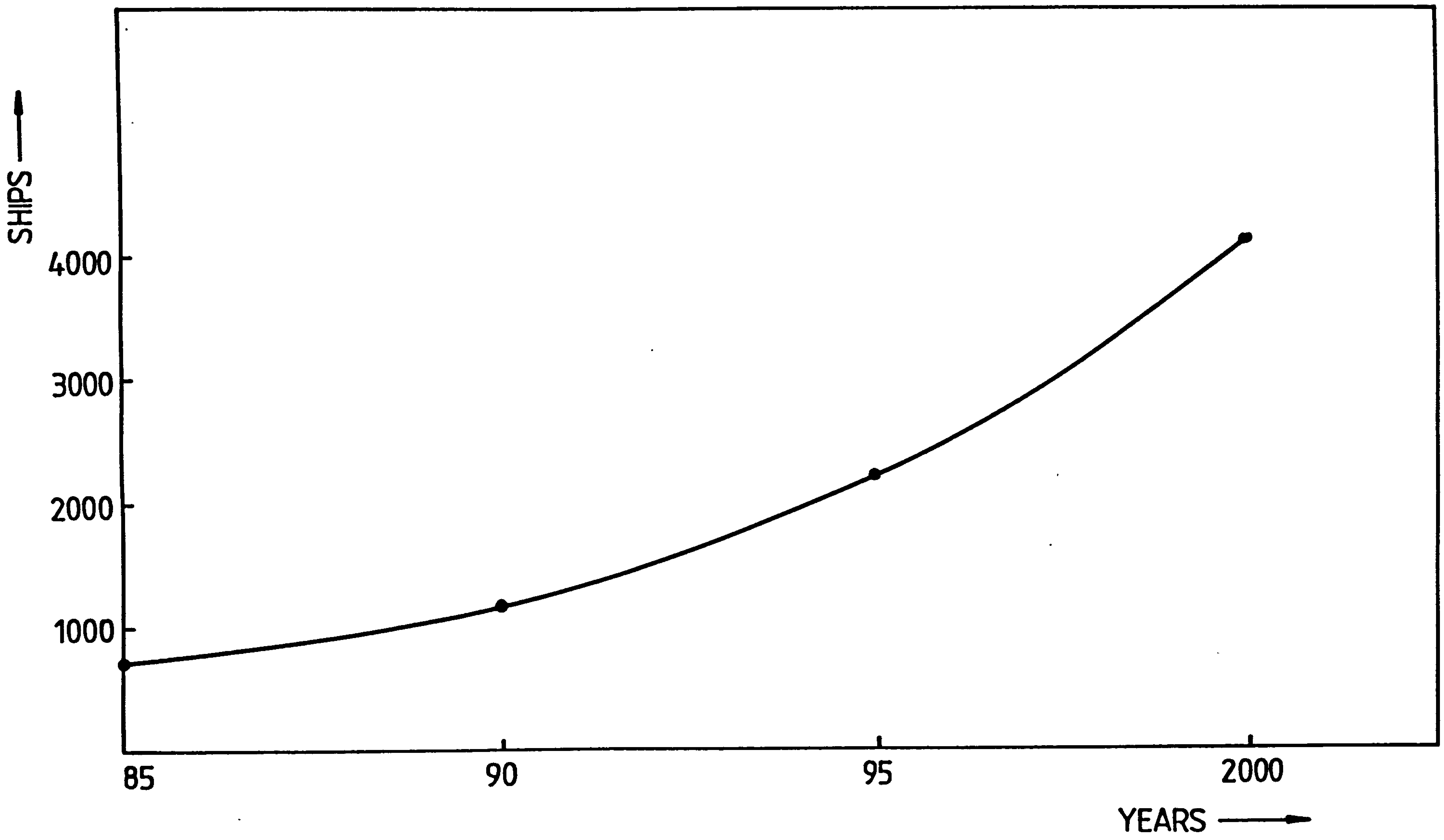

FIGURE 8-14 UM QASR PORT, OPTIMISTIC FORECASTS, CONTAINER TRAFFIC, BERTHS OPERATE 24 H, DEMAND (SHIPS) V. TIME (YEARS)

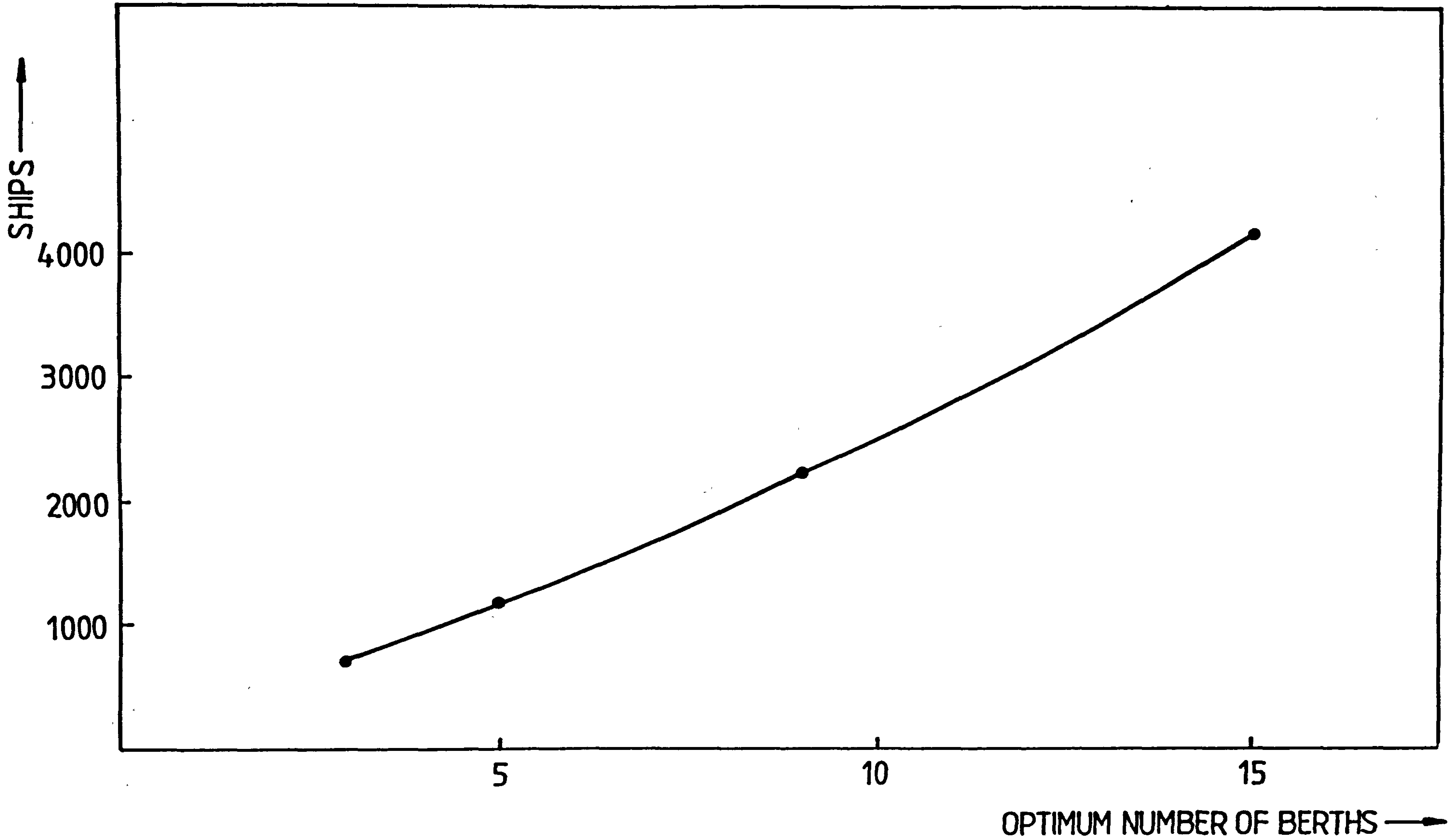

FIGURE 8-15 UM QASR PORT, OPTIMISTIC FORECASTS, CONTAINER TRAFFIC, BERTHS OPERATE 24 H, DEMAND (SHIPS) V. OPTIMUM NUMBER OF BERTHS

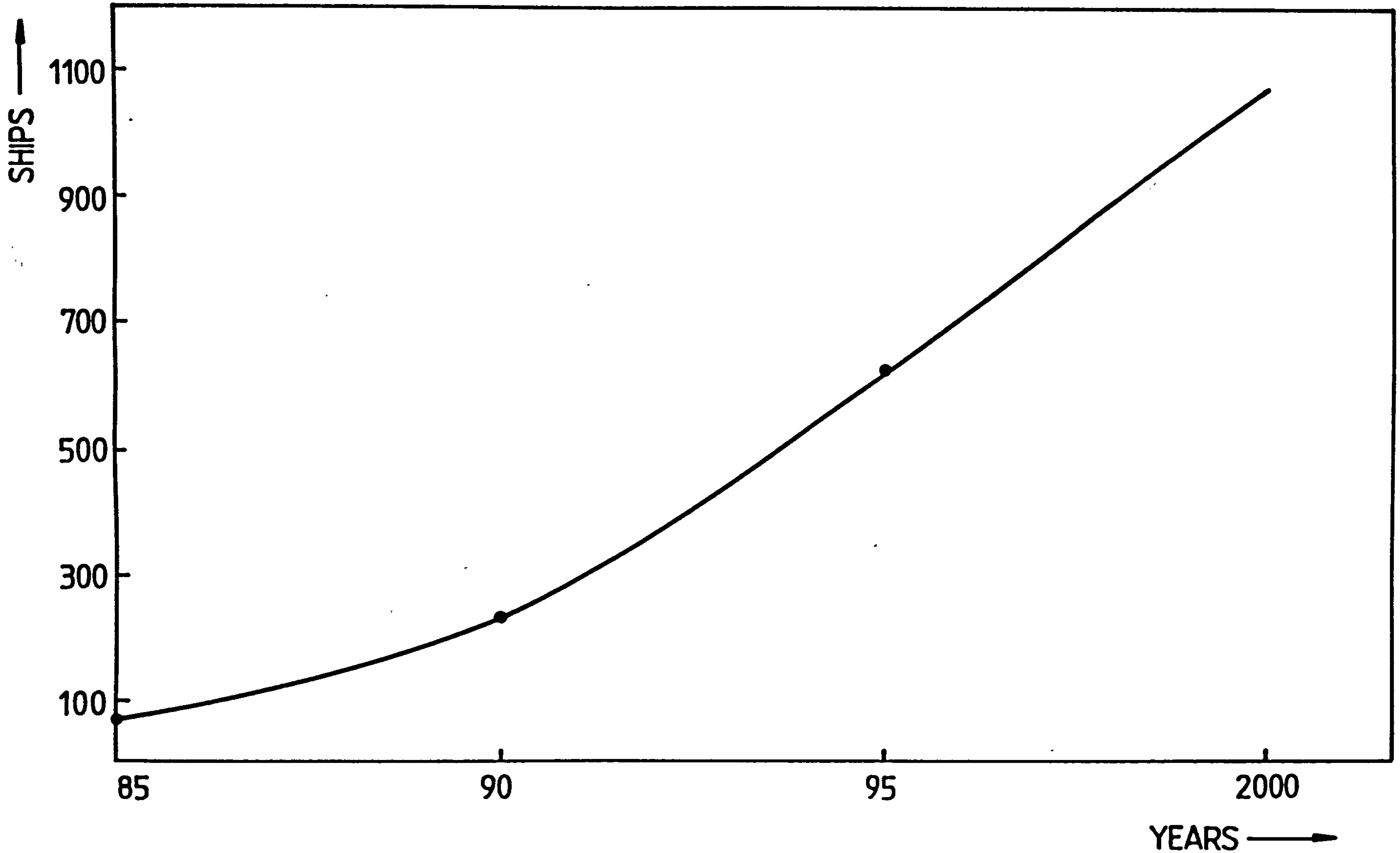

FIGURE 8-16 UM QASR PORT, PESSIMISTIC FORECASTS, GENERAL CARGO TRAFFIC, BERTHS OPERATE 12 H, DEMAND (SHIPS) V. TIME (YEARS).

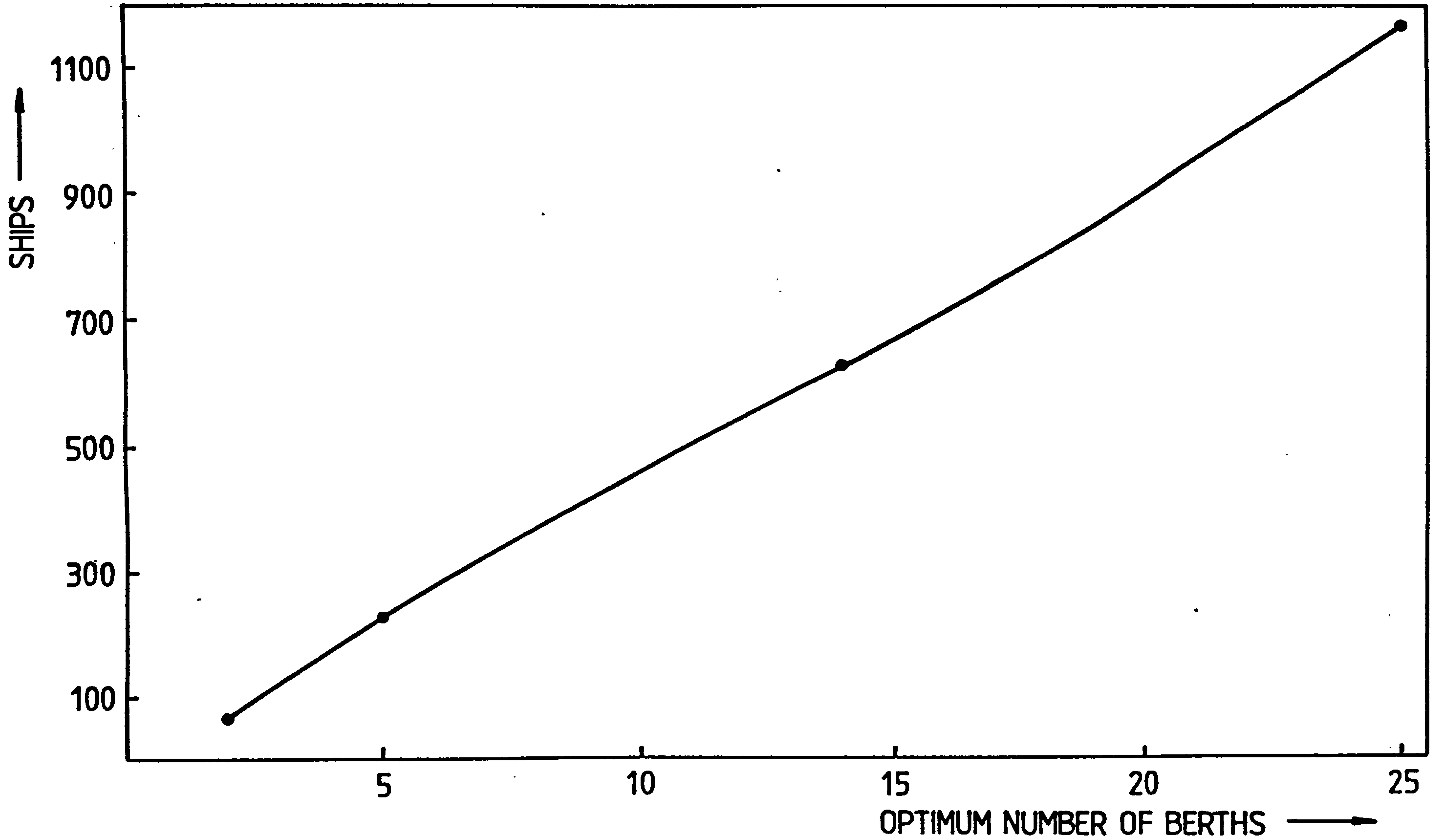

FIGURE 8-17 UM QASR PORT, PESSIMISTIC FORECASTS, GENERAL CARGO TRAFFIC, BERTHS OPERATE 12 H, DEMAND (SHIPS) V. OPTIMUM NUMBER OF BERTHS

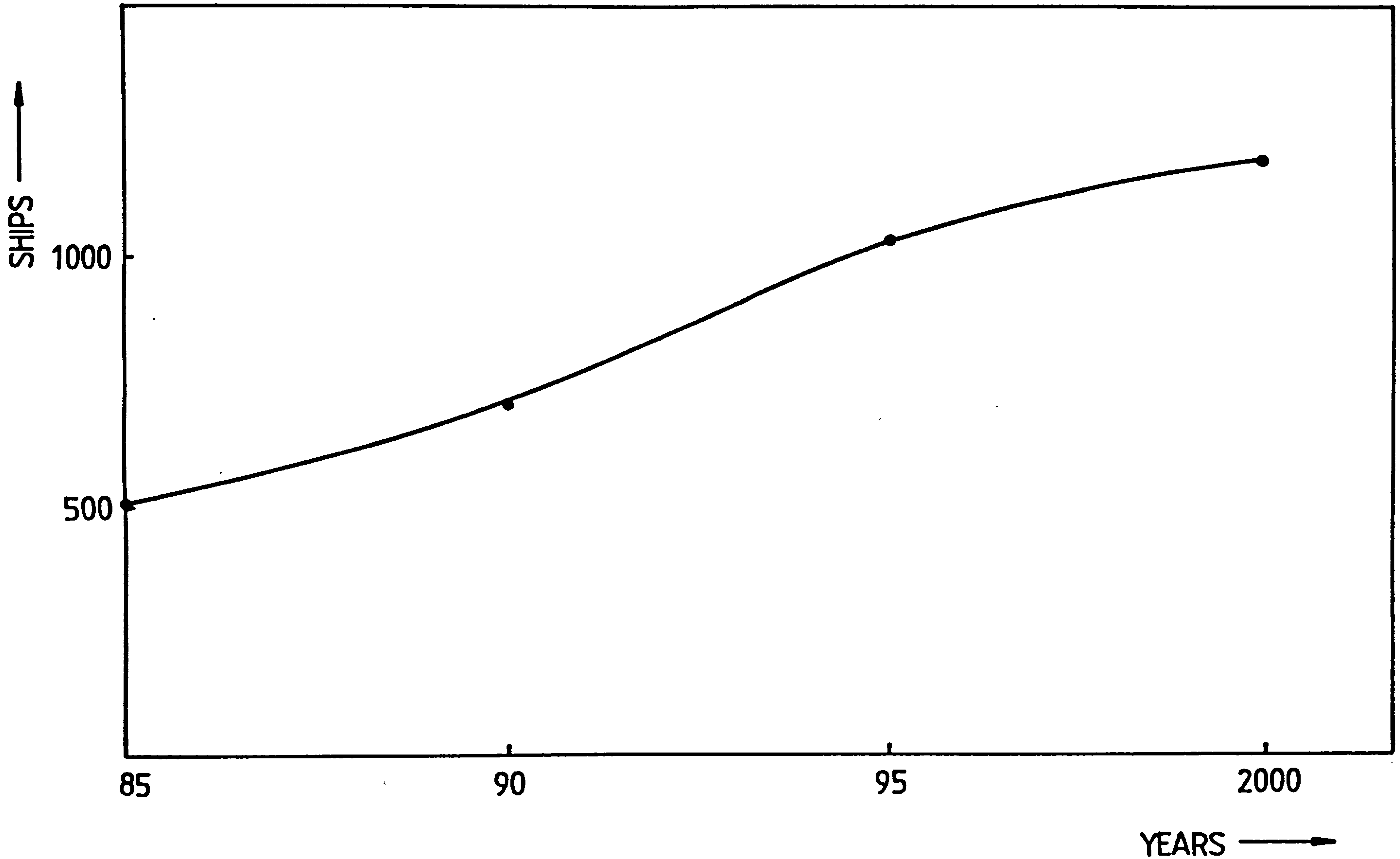

FIGURE 8-18 UM QASE PORT PESSIMISTIC FORECASTS, CONTAINER TRAFFIC, BERTHS OPERATE 12H, DEMAND (SHIPS) V. TIME (YEARS)

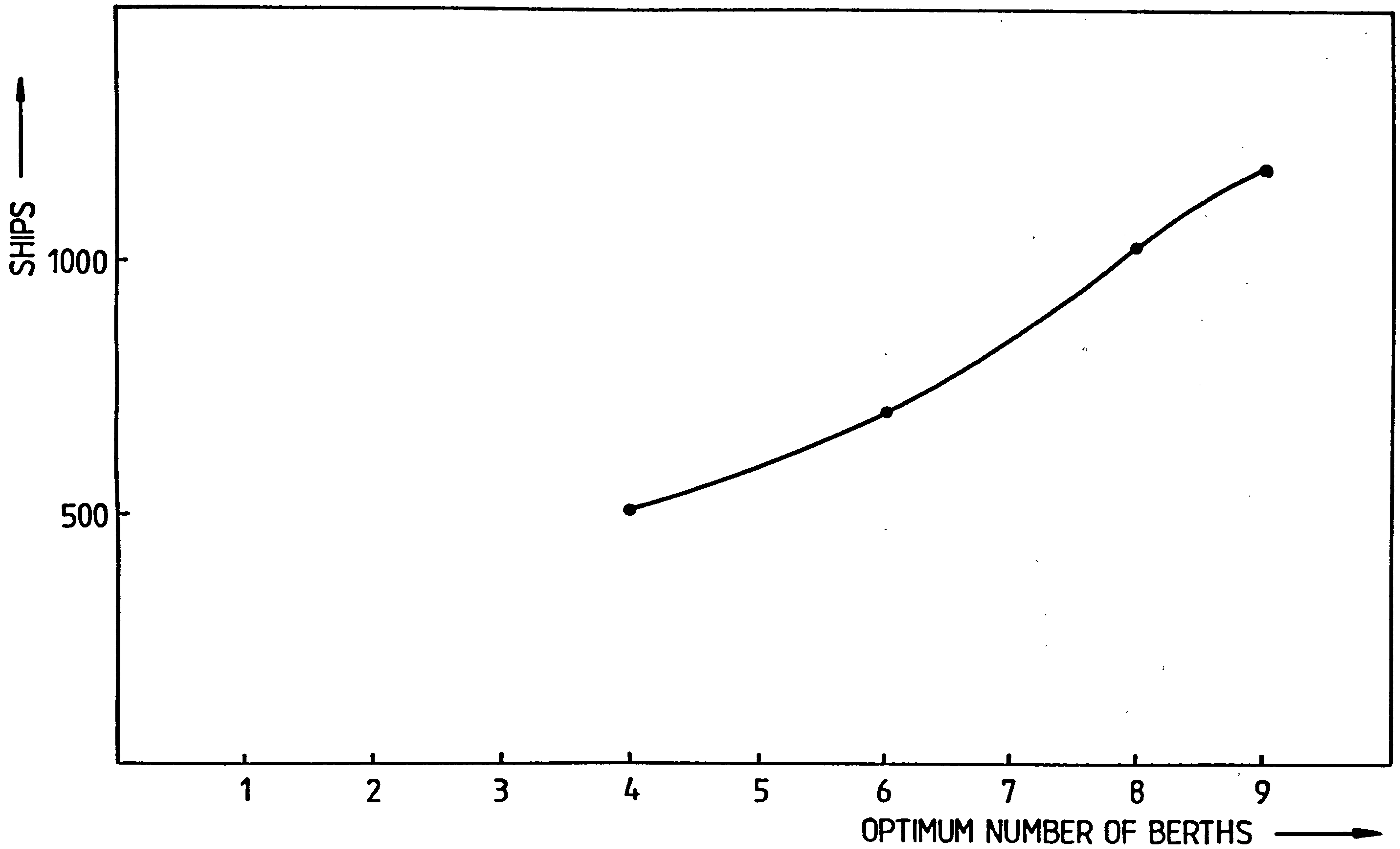

FIGURE 8-19 UM QASR PORT, PESSIMISTIC FORECASTS, CONTAINER TRAFFIC, BERTHS OPERATE 12 H, DEMAND (SHIPS) V. OPTIMUM NUMBER OF BERTHS

are plotted for the year 1985 because only 2 berths are required to service 73 ships (see Table 6.26), in Table 8.17, 4 berths were used because there are already 4 general cargo berths.

To summarise, three models were developed in this chapter. The routing model was developed to determine the optimum number of ships that can be served at a limited capacity port so that the rest of the ships can be diverted to other ports. The minimum cost point model was developed to determine the optimum number of berths for the years simulated. Finally the minimum cost point model was extended to result in an optimal berthing capacity at any future time period within the planning horizon.

In the next chapter, detailed conclusions on the whole study will be provided.

CHAPTER 9

CONCLUSIONS

This study proceeded on the assumption that port planning and investment processes to determine the optimal berthing capacity required to meet present and future demand for a variety of cargo classes need to be modelled in an integrated dynamic way.

An attempt has been made in this study to provide modelling frameworks for forecasting, simulation and investment appraisal and to link the above three models together to produce a dynamic model resulting in optimal decision strategies for any future time period within the planning horizon.

From the models developed, several groups of conclusions are drawn. They refer to the methods, to the implications of the use of the models to determine optimal port policies, and to the research areas which have been identified in the process of formulating the port planning and investment problems.

9.1 Conclusions on Methods

In the theoretical analysis and research methodologies (Chapter 4), outlines for the various methods and techniques, their strengths, weakness, appropriateness and suitability as they apply to port planning and investment were provided. This furnishes the port planners with basic guides in their difficult task to choose the appropriate methods for specific situations. The way forecasting, simulation and investment appraisal interact together to produce an integrated dynamic model was also provided.

The unavailability of forecasting models linking aggregate economy and economic growth to seaborne trade, led to the development of forecasting models (Chapter 5), linking economic and population growth, consumption, production and elasticity of demand to seaborne trade. The forecasting models are simple to use and require the minimum of information and they demonstrate their versatility in predicting and updating future demand should unforeseen changes in the economy take place in future. Since the problem dealt with is a long range planning one, three forecasts were provided covering a wide range of possible economic growth in order to minimise the risk of deviations.

The limited and scarce literature on simulation and simulation models concerning port operations, led to the development of a simulation model (Chapter 6) providing port planners with a flexible planning tool and a means for evaluating existing and future terminal capacity. The model was programmed for the use of a microcomputer thus providing a cheap method of achieving extremely useful results through simulating various demand levels for different port configurations and existing and alternative operating procedures. The simulation model is developed so that additions and revisions to any one of the components may be accomplished easily and quickly for individual program subroutines without affecting the other parts of simulation, thereby extending the use of the model to a variety of ports with different characteristics such as different arrival and service time distributions.

The lack of a systematic appraisal technique which appears to have led to over investment, under investment or misplaced investment, led to the development of investment models (Chapter 8) where sound and realistic decisions on port investment could be made leading to the selection of the most advantageous plans. The models developed in the last chapter demonstrate their versatility, flexibility and usefulness in being able to arrive at optimal decision strategies for any desired future time period within the planning horizon. This was achieved through linking demand, time, congestion and total costs in an integrated way by using only 4 points in time instead of the 16 required, thereby reducing the immense amount, time and cost of work by 75 per cent.

9.2 Conclusions for Port Policy and Investment

The models developed in this study were based on the analysis of several demand alternatives, different port configurations and port operating policies. The use of such models to determine the optimal port policies have the following implications:-

1. The most efficient use of capital resources would be a clear possibility for port developers since optimal berthing capacity at minimal cost was achieved.

2. It would be possible to arrive at optimal investment policies based on different operational characteristics of the port since the simulation and investment models can readily deal with different working shifts per day and different working days per year.

3. From the stand point of financing the expansion in new berths, it would be possible to obtain the maximum benefit from capital as it is made available to the port authority. The last model developed in the previous chapter results in the optimum number of berths required at any future time period within the planning horizon, thus providing the financing authority with the flexibility of choosing from a number of alternative optimal development policies such as yearly, 2 yearly, ... 5 yearly, ... etc. investment programmes.

9.3 Conclusions on Further Research

From the models developed, congestion cost paid in penalties was reduced to a minimum hence providing the largest benefit by reducing the turn-round time of ships and allowing the efficient flow of goods in and out of the country. Capital tied up in goods is also freed to be utilised more efficiently where it is needed by reducing the amount of time goods spend in port and aboard ships.

Since this study is not concerned with the inland side of port operations, the simulation and investment appraisal models could be expanded to incorporate the inland side of the operations and the transport and distribution processes of the commodities to their final destinations.

Such processes may require the use of other optimisation techniques such as mathematical programming for scheduling and sequencing the commodities into a multiport network, that is, a sea-to-land transportation network. The aim of such a study is to achieve minimum total transportation cost by optimum mix of port and transport system components such as road, rail and river.

Another major area of research resulting from this study could be the maximisation of profits from port operations. Since optimal capacity at minimal cost has been achieved, the appropriate port tariffs and dues resulting in maximum profits could then be determined in a variety of situations.

Firstly, in a monopolistic situation, that is, what changes in port tariffs and dues should the ports make when they are the only ones in the region and could cater for the needs of neighbouring countries.

Secondly, in a situation where the ports are in direct competition with other modes of transport.

Thirdly, in a fully competitive situation where ports of neighbouring countries providing similar or better services are in competition with the ports in question, all trying to capture an increased share of the international traffic by trans-shipment or by inland routing.

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APPENDICES

LIST OF APPENDICES

APPENDIX A

A.1 MOST LIKELY FORECASTS

1. Alcohol, Wine, Tobacco and Cigarettes (where $\alpha = 1$)

$$I_{85} = 10385\ (1 + 0.11)^{6} = 19424 \text{ tons}$$
$$I_{90} = 10385\ (1 + 0.11)^{11} = 32731 \text{ tons}$$
$$I_{95} = 10385\ (1 + 0.11)^{16} = 55153 \text{ tons}$$
$$I_{2000} = 10385\ (1 + 0.11)^{21} = 92937 \text{ tons}$$

2. Automobiles and Parts (where $\alpha = 1$)

$$I_{85} = 16747\ (1 + 0.11)^{6} = 31324 \text{ tons}$$
$$I_{90} = 16747\ (1 + 0.11)^{11} = 52782 \text{ tons}$$
$$I_{95} = 16747\ (1 + 0.11)^{16} = 88941 \text{ tons}$$
$$I_{2000} = 16747\ (1 + 0.11)^{21} = 149871 \text{ tons}$$

3. Coal and Coke (where $\alpha = 0.73$, $PR_r = 17.5\%$)

$$I_{85} = 36101\ (1 + 0.73 \times 0.11)^{6} - 30000\ (1 + 0.175) = -19725$$

Therefore no more imports will be required from the year 1985 onwards.

4. Cotton, Wool, Silk and Nylon Products (where $\alpha = 0.5$)

$$I_{85} = 15262\ (1 + 0.5 \times 0.11)^{6} = 20425 \text{ tons}$$
$$I_{90} = 15262\ (1 + 0.5 \times 0.11)^{11} = 26103 \text{ tons}$$
$$I_{95} = 15262\ (1 + 0.5 \times 0.11)^{16} = 33315 \text{ tons}$$
$$I_{2000} = 15262\ (1 + 0.5 \times 0.11)^{21} = 42519 \text{ tons}$$

5. <u>Cement</u> (where α = 1, PR_r = 0.24)

I_{85} = $5462491\ (1 + 0.11)^6 - 5300000\ (1 + 0.24)^6 = -9049517$ tons

Hence no imports of cement will be required.

6. <u>Drugs and Chemicals</u> (where α = 1)

$I_{85} = 126541\ (1 + 0.11)^6 = 236684$ tons

$I_{90} = 126541\ (1 + 0.11)^{11} = 398826$ "

$I_{95} = 126541\ (1 + 0.11)^{16} = 672045$ "

$I_{2000} = 126541\ (1 + 0.11)^{21} = 1{,}132436$ tons

7. <u>Electric Goods</u> (where α = 1)

$I_{85} = 25461\ (1 + 0.11)^6 = 47622$ tons

$I_{90} = 25461\ (1 + 0.11)^{11} = 80247$ "

$I_{95} = 25461\ (1 + 0.11)^{16} = 135220$ "

$I_{2000} = 25461\ (1 + 0.11)^{21} = 227855$ tons

8. <u>Food</u> (where α = 2 up to 1985, and the country will be self sufficient by 1990)

$I_{85} = 143191\ (1 + 2 \times 0.11)^6 = 472144$ tons

$I_{90} = 0$

$I_{95} = 0$

$I_{2000} = 0$

9. <u>Glassware</u> (where α = 0.5)

$I_{85} = 14344\ (1 + 0.5 \times 0.11)^6 = 19778$ tons

$I_{90} = 14344\ (1 + 0.5 \times 0.11)^{11} = 25849$ "

$I_{95} = 14344\ (1 + 0.5 \times 0.11)^{16} = 33784$ "

$I_{2000} = 14344\ (1 + 0.5 \times 0.11)^{21} = 44154$ "

10. <u>Gunnies (where $\alpha = 0.81$)</u>

It was assumed that imports will increase until 1990, and then decrease by 10% to the end of the century. Hence the model will be:

$I_t = I_p\ (1 + 0.81 \times 0.11)^t$ up to 1990

$I_t = I_{90}\ (1 - 0.1)^t$ up to 2000

$$I_{85} = 13385\ (1 + 0.81 \times 0.11)^6 = 22448 \text{ tons}$$
$$I_{90} = 13385\ (1 + 0.81 \times 0.11)^{11} = 34539 \text{ tons}$$
$$I_{95} = I_{90}\ (1 - 0.01)^5 = 20395 \text{ tons}$$
$$I_{2000} = I_{90}\ (1 - 0.01)^{10} = 12043 \text{ tons}$$

11. <u>Iron (where $\alpha = 1$)</u>

$$I_{85} = 1188485\ (1 + 0.11)^6 = 2222960 \text{ tons}$$
$$I_{90} = 1188485\ (1 + 0.11)^{11} = 3745816 \text{ tons}$$
$$I_{95} = 1188485\ (1 + 0.11)^{16} = 6311918 \text{ tons}$$
$$I_{2000} = 1188485\ (1 + 0.11)^{21} = 10635949 \text{ tons}$$

12. <u>Grains (where $\beta = 1$)</u>

It was mentioned that 8,000,000 mesharas will be cultivated and harvested before 1985 and hence the local production for grains in 1985 will be:
8,000,000 x 170/1000 = 1,360,000 tons, then increasing at 10%.

$$I_{85} = 2322521\ (1 + 0.034)^6 - 1360000 = 1478460 \text{ tons}$$
$$I_{90} = 2322521\ (1 + 0.034)^{11} - 1360000\ (1 + 0.1)^5 = 1164653 \text{ tons}$$
$$I_{95} = 2322521\ (1 + 0.034)^{16} - 1360000\ (1 + 0.1)^{10} = 437921 \text{ tons}$$
$$I_{2000} = 2322521\ (1 + 0.034)^{21} - 1360000\ (1 + 0.1)^{15} = -994100 \text{ tons}$$

Therefore in the year 2000 the country is expected to export nearly 1,000,000 tons of grains.

13. Leather (where $\alpha = 0.7$, $PR_r = 0.125$)

$$I_{85} = 29683\ (1 + 0.7 \times 0.11)^6 - 26000\ (1 + 0.125)^6 = -6386 \text{ tons}$$

Hence no more leather imports.

14. Machinery (where $\alpha = 1$)

$$I_{85} = 32288\ (1 + 0.11)^6 = 60392 \text{ tons}$$
$$I_{90} = 32288\ (1 + 0.11)^{11} = 101764 \text{ tons}$$
$$I_{95} = 32288\ (1 + 0.11)^{16} = 171478 \text{ tons}$$
$$I_{2000} = 32288\ (1 + 0.11)^{21} = 288950 \text{ tons}$$

15. Oils (where $\beta = 2$)

$$I_{85} = 137045\ (1 + 2 \times .034)^6 = 203371 \text{ tons}$$
$$I_{90} = 137045\ (1 + 2 \times .034)^{11} = 282583 \text{ tons}$$
$$I_{95} = 137045\ (1 + 2 \times .034)^{16} = 392647 \text{ tons}$$
$$I_{2000} = 137045\ (1 + 2 \times .034)^{21} = 545581 \text{ tons}$$

16. Paper (where $\alpha = 1$)

It was assumed that production will continue at the same rate up to the year 1990, and that local production will be 200,000 tons increasing at 15% per annum to the end of the century.

Therefore PR_r = 2.6% up to 1990

PR_r = 15% 1990 onwards

C_p = 200,000 tons in 1990

α = 1

$$I_{85} = 84871\ (1 + 0.11)^6 - 26000\ (1 + 0.026)^6 = 128415 \text{ tons}$$
$$I_{90} = 84871\ (1 + 0.11)^{11} - 200000 = 67492 \text{ tons}$$
$$I_{95} = 84871\ (1 + 0.11)^{16} - 200000\ (1 + .15)^5 = 48470 \text{ tons}$$
$$I_{2000} = 84871\ (1 + 0.11)^{21} - 200000\ (1 + .15)^{10} = -49587 \text{ tons}$$

i.e. no imports in the year 2000.

17. Paints

Referring to page 121 it was assumed the same trend will continue into the future, hence it will be assumed that 2000 tons will be imported annually.

18. Refrigerators (where $\alpha = 1$)

$I_{85} = 25677\ (1 + 0.11)^{6} = 48026$ tons

$I_{90} = 25677\ (1 + 0.11)^{11} = 80927$ "

$I_{95} = 25677\ (1 + 0.11)^{16} = 136368$ "

$I_{2000} = 25677\ (1 + 0.11)^{21} = 229787$ "

19. Sugar (where $\beta = 1$)

$I_{85} = 340254\ (1 + 0.034)^{6} = 415840$ tons

$I_{90} = 340254\ (1 + 0.034)^{11} = 491506$ "

$I_{95} = 340254\ (1 + 0.034)^{16} = 580925$ "

$I_{2000} = 340254\ (1 + 0.034)^{21} = 686630$ "

20. Tar (where $\alpha = 1$, $PR_r = 0.22$)

$I_{85} = 820105\ (1 + 0.11)^{6} - 800000\ (1 + 0.22)^{6} = -1103907$ tons

Therefore, no tar imports.

21. Tea (where $\beta = 1$)

$I_{85} = 29490\ (1 + 0.034)^{6} = 36041$ tons

$I_{90} = 29490\ (1 + 0.034)^{11} = 42599$ "

$I_{95} = 29490\ (1 + 0.034)^{16} = 50350$ "

$I_{2000} = 29490\ (1 + 0.034)^{21} = 59512$ "

22. Timber (where $\propto = 1$)

$I_{85} = 190523\ (1 + 0.11)^{6} = 356357$ tons

$I_{90} = 190523\ (1 + 0.11)^{11} = 600482$ "

$I_{95} = 190523\ (1 + 0.11)^{16} = 1011847$ "

$I_{2000} = 190523\ (1 + 0.11)^{21} = 1705022$ "

23. Others (where $\propto = 1$)

$I_{85} = 1250571\ (1 + 0.11)^{6} = 2339086$ tons

$I_{90} = 1250571\ (1 + 0.11)^{11} = 3941496$ "

$I_{95} = 1250571\ (1 + 0.11)^{16} = 6111650$ "

$I_{2000} = 1250571\ (1 + 0.11)^{21} = 11191567$ "

Table 5-9 shows the most likely forecasts of imports for the years 1985, 1990, 1995 and 2000.

The optimistic forecasts for imports will be worked out on the same basis but GDP_r will be 14% and P_r will be 3.6%, while the pessimistic forecasts will be based on $GDP_r = 8\%$ and $P_r = 3.2\%$. Those forecasts are shown in Tables 5-10 and 5-11 respectively.

A.2 OPTIMISTIC FORECASTS

5. Cement

I_{85} = 5462491 $(1 + 0.14)^6$ - 5300000 $(1 + 0.24)^6$ = -7276616 tonnes

Therefore, no more imports of cement will be required.

6. Drugs and Chemicals

I_{85} = 126541 $(1 + 0.14)^6$ = 277754 tonnes

I_{90} = 126541 $(1 + 0.14)^{11}$ = 534791 "

I_{95} = 126541 $(1 + 0.14)^{16}$ = 1029695 "

I_{2000} = 126541 $(1 + 0.14)^{21}$ = 1982591 "

8. Food

I_{85} = 143191 $(1 + 2 \times 0.14)^6$ = 629760 tonnes

I_{90} = I_{95} = I_{2000} = 0

11. Iron

I_{85} = 1188485 $(1 + 0.14)^6$ = 2608692 tonnes

I_{90} = 1188485 $(1 + 0.14)^{11}$ = 5022813 "

I_{95} = 1188485 $(1 + 0.14)^{16}$ = 9670998 "

I_{2000} = 1188485 $(1 + 0.14)^{21}$ = 18620682 "

12. Grains

I_{85} = 2322521 $(1 + 0.036)^6$ - 1360000 = 1511562 tonnes

I_{90} = 2322521 $(1 + 0.036)^{11}$ - 1360000 $(1 + 0.1)^5$ = 1236729

I_{95} = 2322521 $(1 + 0.036)^{16}$ - 1360000 $(1 + 0.1)^{10}$ = 562439

I_{2000} = 2322521 $(1 + 0.036)^{21}$ - 1360000 $(1 + 0.1)^{15}$ = -799993

Hence in the year 2000 exports will be 8000,000 tonnes.

15. <u>Oils</u>

$I_{85} = 137045\ (1 + 2 \times 0.036)^{6} = 207985$ tonnes

$I_{90} = 137045\ (1 + 2 \times 0.036)^{11} = 294446$ "

$I_{95} = 137045\ (1 + 2 \times 0.036)^{16} = 416849$ "

$I_{2000} = 137045\ (1 + 2 \times 0.036)^{21} = 590138$ "

19. <u>Sugar</u>

$I_{85} = 340254\ (1 + 0.036)^{6} = 420689$ tonnes

$I_{90} = 340254\ (1 + 0.036)^{11} = 502065$ "

$I_{95} = 340254\ (1 + 0.036)^{16} = 599182$ "

$I_{2000} = 340254\ (1 + 0.036)^{21} = 715085$ "

22. <u>Timber</u>

$I_{85} = 190523\ (1 + 0.14)^{6} = 418192$ tonnes

$I_{90} = 190523\ (1 + 0.14)^{11} = 805194$ "

$I_{95} = 190523\ (1 + 0.14)^{16} = 1550333$ "

$I_{2000} = 190523\ (1 + 0.14)^{21} = 2985034$ "

23. <u>Others</u>

$I_{85} = 1250571\ (1 + 0.14)^{6} = 2744975$ tonnes

$I_{90} = 1250571\ (1 + 0.14)^{11} = 5285216$ "

$I_{95} = 1250571\ (1 + 0.14)^{16} = 10176232$ "

$I_{2000} = 1250571\ (1 + 0.14)^{21} = 19593466$ "

A.3 PESSIMISTIC FORECASTS

5. Cement

$I_{85} = I_{90} = I_{95} = I_{2000} = 0$

6. Drugs and Chemicals

$I_{85} = 126541\ (1 + 0.08)^{6} = 200804$ tonnes

$I_{90} = 126541\ (1 + 0.08)^{11} = 295048$ "

$I_{95} = 126541\ (1 + 0.08)^{16} = 433522$ "

$I_{2000} = 126541\ (1 + 0.08)^{21} = 636986$ "

8. Food

$I_{85} = 143191\ (1 + 2 \times 0.08)^{6} = 348870$ tonnes

$I_{90} = I_{95} = I_{2000} = 0$

11. Iron

$I_{85} = 1188485\ (1 + 0.08)^{6} = 1885976$ tonnes

$I_{90} = 1188485\ (1 + 0.08)^{11} = 2771118$ "

$I_{95} = 1188485\ (1 + 0.08)^{16} = 4071681$ "

$I_{2000} = 1188485\ (1 + 0.08)^{21} = 5982636$ "

12. Grains

$I_{85} = 2322521\ (1 + 0.032)^{6} - 1360000 = 1445678$ tonnes

$I_{90} = 2322521\ (1 + 0.032)^{11} - 1360000\ (1 + 0.1)^{5} = 1093957$ tonnes

$I_{95} = 2322521\ (1 + 0.032)^{16} - 1360000\ (1 + 0.1)^{10} = 316966$ "

$I_{2000} = 2322521\ (1 + 0.032)^{21} - 1360000\ (1 + 0.1)^{15} = -1180842$ "

Hence in the year 2000 exports will be 1200000 tonnes.

15. Oils

I_{85} = $137045\ (1 + 2 \times 0.032)^{6}$ = 198844 tonnes
I_{90} = $137045\ (1 + 2 \times 0.032)^{11}$ = 271157 "
I_{95} = $137045\ (1 + 2 \times 0.032)^{16}$ = 369767 "
I_{2000} = $137045\ (1 + 2 \times 0.032)^{21}$ = 504240 "

19. Sugar

I_{85} = $340254\ (1 + 0.032)^{6}$ = 411037 tonnes
I_{90} = $340254\ (1 + 0.032)^{11}$ = 481149 "
I_{95} = $340254\ (1 + 0.032)^{16}$ = 563220 "
I_{2000} = $340254\ (1 + 0.032)^{21}$ = 659290 "

22. Timber

I_{85} = $190523\ (1 + 0.08)^{6}$ = 302336 tonnes
I_{90} = $190523\ (1 + 0.08)^{11}$ = 444230 "
I_{95} = $190523\ (1 + 0.08)^{16}$ = 652720 "
I_{2000} = $190523\ (1 + 0.08)^{21}$ = 952720 "

23. Others

I_{85} = $1250574\ (1 + 0.08)^{6}$ = 1984503 tonnes
I_{90} = $1250574\ (1 + 0.08)^{11}$ = 2915887 "
I_{95} = $1250574\ (1 + 0.08)^{16}$ = 4284394 "
I_{2000} = $1250574\ (1 + 0.08)^{21}$ = 6295181 "

APPENDIX B

B.1 MOST LIKELY FORECASTS

1. Dates ($PR_r = 0.006$)

$E_{85} = 204277\ (1 + 0.006)^6 = 211742$ tonnes

$E_{90} = 204277\ (1 + 0.006)^{11} = 218171$ "

$E_{95} = 204277\ (1 + 0.006)^{16} = 224795$ "

$E_{2000} = 204277\ (1 + 0.006)^{21} = 231620$ "

2. Fertilisers ($PR_r = 0.20$ until 1990)

$E_{85} = 146709\ (1 + 0.20)^6 = 438070$ tonnes

$E_{90} = 146709\ (1 + 0.20)^{11} = 1090060$ "

Therefore $E_{90} = E_{95} = E_{2000} = 1{,}000{,}000$ tonnes, the designed capacity.

8. Sulphur ($PR = 0.09$)

$E_{85} = 601498\ (1 + 0.09)^6 = 1023866$ tonnes

$E_{90} = 601498\ (1 + 0.09)^{11} = 1575345$ "

Therefore $E_{90} = E_{95} = E_{2000} = 1{,}500{,}000$ tonnes, the designed capacity.

9. Urea

It was assumed that exports of urea will be 750,000 tonnes by 1985 increasing to reach 1,000,000 tonnes in 1990.

Therefore $E_{85} = 750{,}000$ tonnes

$E_{90} = E_{95} = E_{2000} = 1{,}000{,}000$ tonnes, the designed capacity.

11. Others

As can be seen from Table 5-12, the rate of growth in the volume of exports of this commodity has been negligible over the years 74-79 and hence the average volume over these years will be assumed to be exported up to the end of this century, which is 126000 tonnes.

Phosphates

It was assumed in the previous section that the initial capacity in 1985 will be 250,000 tonnes, and the designed capacity of 1,500,000 tonnes is to be reached by 1990.

Therefore E_{85} = 250,000 tonnes

$$E_{90} = E_{95} = E_{2000} = 1{,}500{,}000 \text{ tonnes.}$$

B.2 OPTIMISTIC FORECASTS

2. Fertilisers

$E_{85} = 146709\ (1 + 0.23)^6 = 508027$ tonnes

$E_{90} = E_{95} = E_{2}000 = 1{,}000{,}000$ tonnes

8. Sulphur

$E_{85} = 601498\ (1 + 0.11)^6 = 1125050$ tonnes

$E_{90} = E_{95} = E_{2000} = 1{,}500{,}000$ tonnes

9. Urea

$E_{85} = 276286\ (1 + 0.22)^6 = 910998$ tonnes

$E_{90} = E_{95} = E_{2000} = 1{,}000{,}000$ tonnes

Phosphates

$E_{85} = 250000$ tonnes

$E_{90} = 250\ (1 + 0.49)^5 = 1{,}500{,}000$ tonnes

$E_{90} = E_{95} = E_{2000} = 1{,}500{,}000$ tonnes

B.3 PESSMISTIC FORECASTS

2. Fertilisers

$E_{85} = 146709\ (1 + 0.17)^6 = 376332$ tonnes

$E_{90} = 146709\ (1 + 0.17)^{11} = 825089$ "

$E_{95} = E_{2000} = 1{,}000{,}000$ tonnes

8. Sulphur

$E_{85} = 601498\ (1 + 0.07)^6 = 902686$ tonnes

$E_{90} = 601498\ (1 + 0.07)^{11} = 1266064$ "

$E_{95} = E_{2000} = 1{,}500{,}000$ tonnes

9. Urea

$E_{85} = 276286\ (1 + 0.14)^6 = 606440$ tonnes

$E_{90} = E_{95} = E_{2000} = 1{,}000{,}000$ tonnes

Phosphates

$E_{85} = 250{,}000$

$E_{90} = 250{,}000\ (1 + 0.37)^5 = 1206543$ tonnes

$E_{95} = E_{2000} = 1{,}500{,}000$ tonnes

APPENDIX C

C-1 CARGO CLASSES FOR İMPORT COMMODITIES[1]

	Cargo Class					Quantity (ton) Based on Most Likely Forecasts				
Item	79*	85	90	95	2000	79	85	90	95	2000
1. Alcohol	C	C	C	C	C	10,385	19,424	32,731	55,153	92,937
2. Automobiles	G	G	G	G	C	16,747	31,324	52,782	88,941	149,871
3. Coal	G	G	G	G	G	6,101	-	-	-	-
4. Cotton	C	C	C	C	C	15,262	20,425	26,103	33,315	42,519
5. Cement	B.C	B.C	B.C	B.C	B.C	162,491	-	-	-	-
6. Drugs	G	50%C	C	C	C	126,541	236,684	398,826	672,045	1,132,436
7. Electrical	C	C	C	C	C	25,461	47,622	80,247	135,220	227,855
8. Food	C	C	C	C	C	143,191	472,144	-	-	-
9. Glassware	C	C	C	C	C	14,344	19,778	25,849	33,784	44,154
10. Gunnies	G	G	G	G	G	13,385	22,448	34,539	20,395	12,043
11. Iron	G	G	G	G	G	1,188,485	2,222,960	3,745,816	6,311,918	10,635,949
12. Grains	BK	BK	BK	BK	BK	1,610,521	1,478,460	1,164,653	437,921	-
13. Leather	C	C	C	C	C	3,683	-	-	-	-
14. Machinery	G	50%C	50%C	50%C	50%C	32,288	60,392	101,764	171,478	288,950
15. Oils	BK	BK	BK	BK	BK	137,045	203,371	282,583	392,647	545,581
16. Paper	C	C	C	C	C	58,871	128,415	67,492	48,470	-
17. Paints	G	C	C	C	C	1,613	2,000	2,000	2,000	2,000
18. Refrigerators	C	C	C	C	C	25,677	48,026	80,927	136,368	229,787
19. Sugar	G	BK	BK	BK	BK	304,254	415,840	491,506	580,925	686,630
20. Tar	G	G	G	G	G	20,105	-	-	-	-
21. Tea	G	G	G	G	G	29,490	36,041	42,599	50,350	59,512
22. Timber	G	G	G	G	G	190,523	356,357	600,482	1,011,847	1,705,022
23. Others	G	75%G 25%C	50%G 50%C	50%C 50%C	50%G 50%C	1,250,571	2,339,086	3,941,496	6,641,650	11,191,567

Key:
C - 100% containerised cargo
AC - " automobile carriers
G - " general cargo
B.C - " bagged cement
BK - " bulk grain, or bulk oil or bulk sugar

[1] Source: Estimation of Iraqi Port Organisation

* actual imports by class of cargo

C-2 IMPORT CARGO CLASS : MOST LIKELY FORECASTS

GENERAL CARGO

Item	85	90	95	2000
2. Automobiles & parts	31,324	52,782	88,941	-
3. Coal	-	-	-	-
6. Drugs and chemicals	118,342	-	-	-
10. Gunnies	22,448	34,539	20,395	12,043
11. Iron and steel	2,222,960	3,745,816	6,311,918	10,635,949
14. Machinery	30,196	50,882	85,739	144,475
20. Tar	-	-	-	-
21. Tea	36,041	42,599	50,350	59,512
22. Timber	356,357	600,482	1,011,847	1,705,022
23. Others	1,754,314	1,970,748	3,320,825	5,595,783
	4,571,982	6,497,848	10,890,015	18,152,784

CONTAINER

1. Alcohol	19,424	32,731	55,153	92,937
4. Cotton	20,425	26,103	33,315	42,519
6. Drugs	118,342	398,826	672,045	1,132,436
7. Electrical	47,622	80,247	135,220	227,855
8. Food	472,144	-	-	-
9. Glassware	19,778	25,849	33,784	44,154
13. Leather	-	-	-	-
14. Machinery	30,196	50,882	85,739	144,475
16. Paper	128,415	67,492	48,470	-
17. Paints	2,000	2,000	2,000	2,000
18. Refrigerators	48,026	80,927	136,368	229,787
23. Others	584,772	1,970,748	3,320,825	5,595,783
	1,491,144	2,735,805	4,522,919	7,511,947

12. Grains	1,478,460	1,164,653	437,921	-

15. Oil	203,371	282,583	392,647	545,581

19. Sugar	415,840	491,506	580,925	686,630

2. Automobiles	-	-	-	149,871
Grand Totals	8,160,797	11,172,395	16,824,427	27,046,813

C-3 IMPORT CARGO CLASS : OPTIMISTIC FORECASTS

GENERAL CARGO

Item	85	90	95	2000
2. Automobiles & parts	31,324	52,782	88,941	-
3. Coal	-	-	-	-
6. Drugs and chemicals	138,877	-	-	-
10. Gunnies	22,448	35,539	20,395	12,043
11. Iron and steel	2,608,692	5,022,813	9,670,998	18,620,682
14. Machinery	30,196	50,882	85,739	144,475
20. Tar	-	-	-	-
21. Tea	36,041	42,599	50,350	59,512
22. Timber	418,192	805,194	1,550,333	2,985,034
23. Others	2,058,731	2,642,608	5,088,116	9,796,733
Total	5,344,501	8,651,417	16,554,872	31,501,479

CONTAINER

1. Alcohol	19,424	32,731	55,153	92,937
4. Cotton	20,425	26,103	33,315	42,519
6. Drugs	138,877	534,791	1,029,695	1,982,591
7. Electrical goods	47,622	80,247	135,220	227,855
8. Food	629,760	-	-	-
9. Glassware	19,778	25,849	33,784	44,154
13. Leather	-	-	-	-
14. Machinery	30,196	50,882	85,739	144,475
16. Paper	128,415	67,492	48,470	-
17. Paints	2,000	2,000	2,000	2,000
18. Refrigerators	48,026	80,927	136,368	229,787
23. Others	686,244	2,642,608	5,088,116	9,796,733
Total	1,770,767	3,543,630	6,647,860	12,446,051

12. Grains	1,511,562	1,236,729	562,439	-

15. Oil	207,985	294,446	416,849	590,138

19. Sugar	420,689	502,065	599,182	715,085

2. Automobiles	-	-	-	149,871
Grand Totals	9,255,504	14,228,287	24,781,202	45,636,624

C-4 IMPORTS CARGO CLASS : PESSIMISTIC FORECASTS

GENERAL CARGO

Item	85	90	95	2000
2. Automobiles & parts	31,324	52,782	88,941	-
3. Coal	-	-	-	-
6. Drugs and chemicals	100,402	-	-	-
10. Gunnies	22,448	34,539	20,395	12,043
11. Iron and steel	1,885,976	2,771,118	4,071,681	5,982,636
14. Machinery	30,196	50,882	85,739	144,475
20. Tar	-	-	-	-
21. Tea	36,041	42,599	50,350	59,512
22. Timber	302,336	444,230	652,720	952,720
23. Others	1,488,377	1,457,943	2,142,197	3,147,591
Total	3,897,100	4,854,093	7,112,023	10,298,976

CONTAINER

1. Alcohol	19,424	32,731	55,153	92,937
4. Cotton	20,425	26,103	33,315	42,519
6. Drugs	100,402	295,048	433,522	636,986
7. Electrical goods	47,622	80,247	135,220	227,855
8. Food	348,870	-	-	-
9. Glassware	19,778	25,849	33,784	44,154
13. Leather	-	-	-	-
14. Machinery	30,196	50,882	85,739	144,475
16. Paper	128,415	67,492	48,470	-
17. Paints	2,000	2,000	2,000	2,000
18. Refrigerators	48,026	80,927	136,368	229,787
23. Others	496,126.	1,457,944	2,142,197	3,147,590
Total	1,261,284	2,119,223	3,105,768	4,568,303

12. Grains	1,445,678	1,093,957	316,966	-

15. Oil	198,844	271,157	369,767	504,240

19. Sugar	411,037	481,149	563,220	659,290

2. Automobiles	-	-	-	149,871
Grand Totals	7,213,943	8,819,579	11,467,744	16,180,681

C-5 IRAQI EXPORTS ACCORDING TO CARGO CLASS[1]

Item	Cargo Class					Quantity (ton) based on most likely forecasts				
	79*	85	90	95	2000	79	85	90	95	2000
1. Dates	G	G	85%G 15%C	70%G 30%C	50%G 50%C	204,277	211,742	218,171	224,795	231,620
2. Fertilisers	SB	SB	SB	SB	SB	146,709	438,070	1,000,000	1,000,000	1,000,000
3. Fuel oil	G	BK	BK	BK	BK	2,304	-	-	-	-
8. Sulphur	SB	SB	SB	SB	SB	601,498	1,023,866	1,500,000	1,500,000	1,500,000
9. Urea	SB	SB	SB	SB	SB	276,286	750,000	1,000,000	1,000,000	1,000,000
11. Others	G	75%G 25%G	50%G 50%C	50%G 50%C	50%G 50%C	104,066	126,000	126,000	126,000	126,000
12. Grains	BK	BK	BK	BK	BK	-	-	-	-	1,000,000
13. Phosphates	SB	SB	SB	SB	SB	-	250,000	1,500,000	1,500,000	1,500,000

Key: G - 100% General
SB - 100% Solid Bulk
C - 100% Container
BK - 100% Bulk Grain or Oil

[1] Source: Iraqi Ports Organisation

* actual exports by class of cargo

C-6 EXPORTS CARGO CLASS: MOST LIKELY FORECASTS

GENERAL CARGO

Item	85	90	95	2000
1. Dates	211,742	185,445	157,356	115,810
11. Others	94,500	63,000	63,000	63,000
Totals	306,242	248,445	220,356	178,810

SOLID BULKS

2. Fertilisers	438,070	1,000,000	1,000,000	1,000,000
8. Sulphur	1,023,866	1,500,000	1,500,000	1,500,000
9. Urea	750,000	1,000,000	1,000,000	1,000,000
13. Phosphates	250,000	1,500,000	1,500,000	1,500,000
Totals	2,461,936	5,000,000	5,000,000	5,000,000

CONTAINERS

1. Dates	-	32,726	67,439	115,810
11. Others	31,500	63,000	63,000	63,000
Totals	31,500	95,726	130,439	178,810

12. Grains	-	-	-	1,000,000
Grand Totals	2,799,678	5,344,171	5,350,795	6,357,620

C-7 EXPORTS CARGO CLASS: OPTIMISTIC FORECASTS

GENERAL CARGO

Item	85	90	95	2000
1. Dates	211,742	185,445	157,356	115,810
11. Others	94,500	63,000	63,000	63,000
Totals	306,242	248,445	220,356	178,810

SOLID BULKS

2. Fertilisers	508,027	1,000,000	1,000,000	1,000,000
8. Sulphur	1,125,050	1,500,000	1,500,000	1,500,000
9. Urea	910,998	1,000,000	1,000,000	1,000,000
13. Phosphates	250,000	1,500,000	1,500,000	1,500,000
Totals	2,794,075	5,000,000	5,000,000	5,000,000

CONTAINERS

1. Dates	-	32,726	67,439	115,810
11. Others	31,500	63,000	63,000	63,000
Totals	31,500	95,726	130,439	178,810

12. Grains	-	-	-	800,000
Grand Totals	3,131,817	5,344,171	5,350,795	6,157,620

C-8 EXPORTS CARGO CLASS: PESSIMISTIC FORECASTS

GENERAL CARGO

Item	85	90	95	2000
1. Dates	211,742	185,445	157,356	115,810
11. Others	94,500	63,000	63,000	63,000
Totals	306,242	248,445	220,356	178,810

SOLID BULKS

2. Fertilizers	376,332	825,089	1,000,000	1,000,000
8. Sulphur	902,686	1,266,064	1,500,000	1,500,000
9. Urea	606,440	1,000,000	1,000,000	1,000,000
13. Phosphates	250,000	1,206,543	1,500,000	1,500,000
Totals	2,135,458	4,297,696	5,000,000	5,000,000

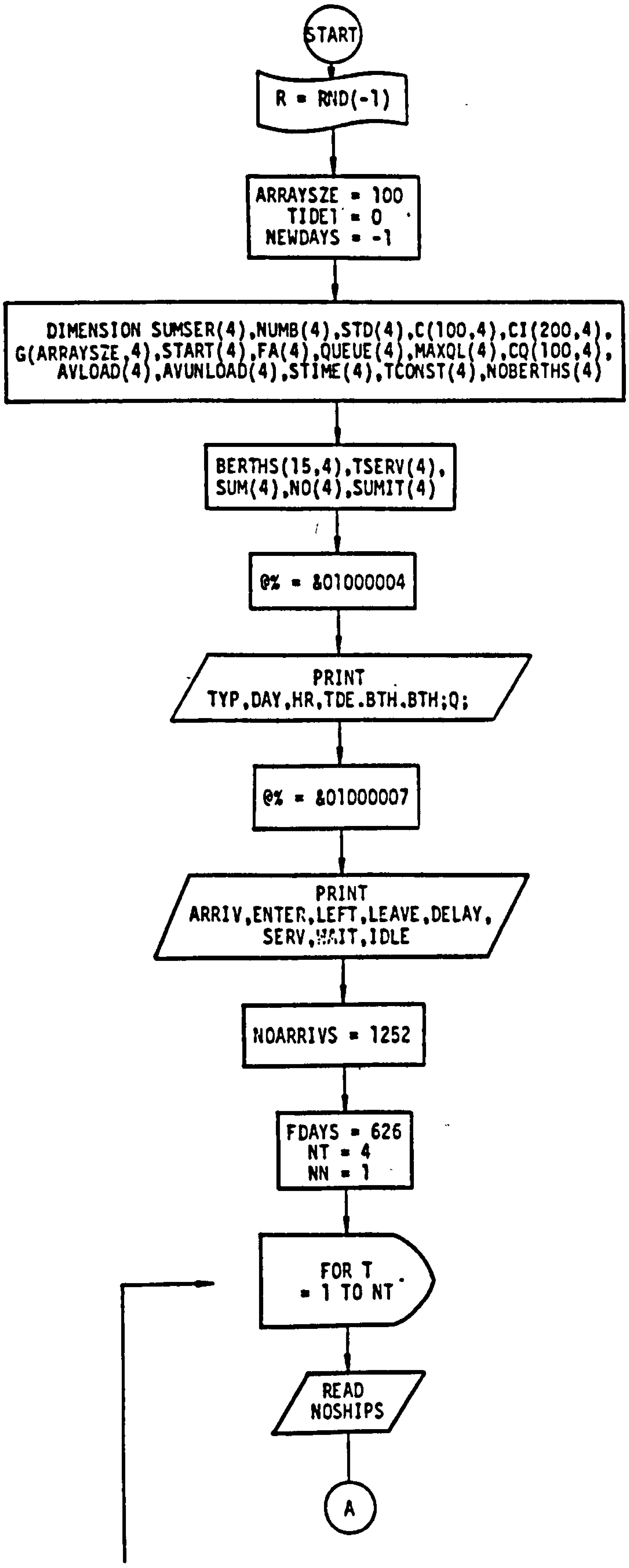
CONTAINERS

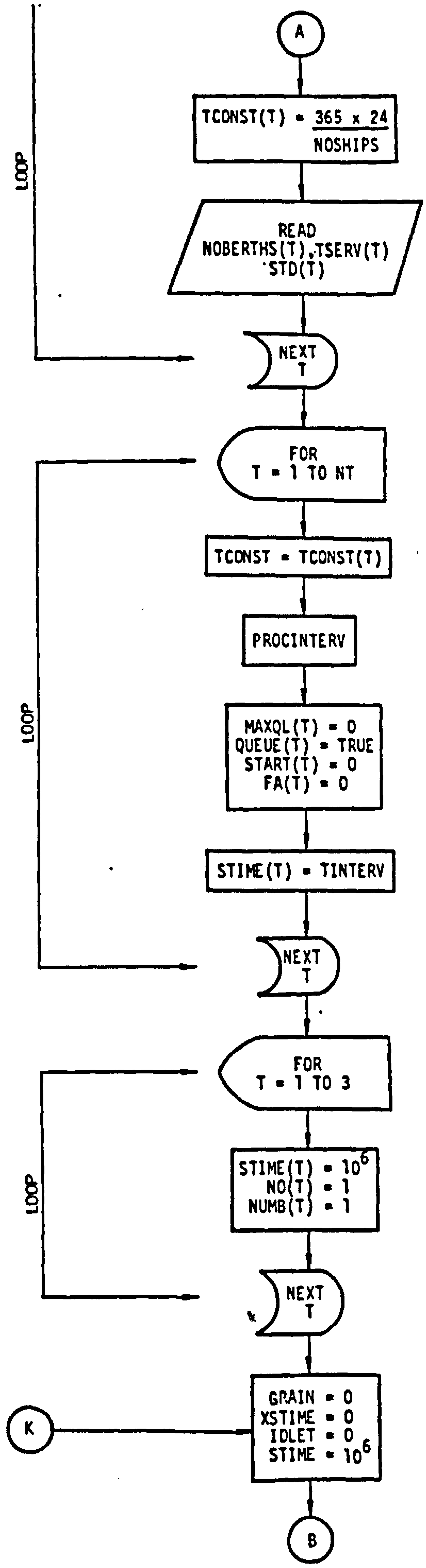
1. Dates	-	32,726	67,439	115,810
11. Others	31,500	63,000	63,000	63,000
Totals	31,5,000	95,726	130,439	178,810

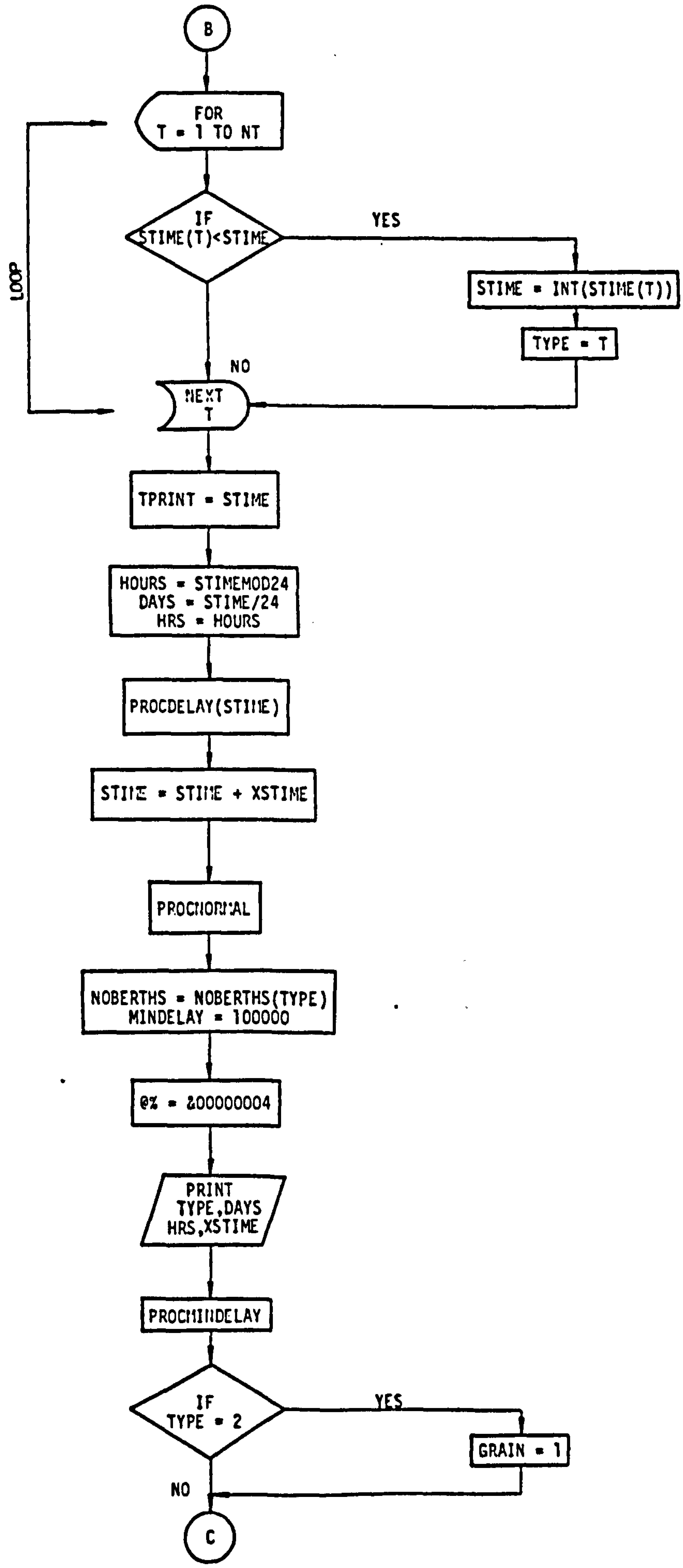
12. Grains	-	-	-	1,200,000
Grand Totals	2,473,200	4,641,867	5,350,795	6,557,620

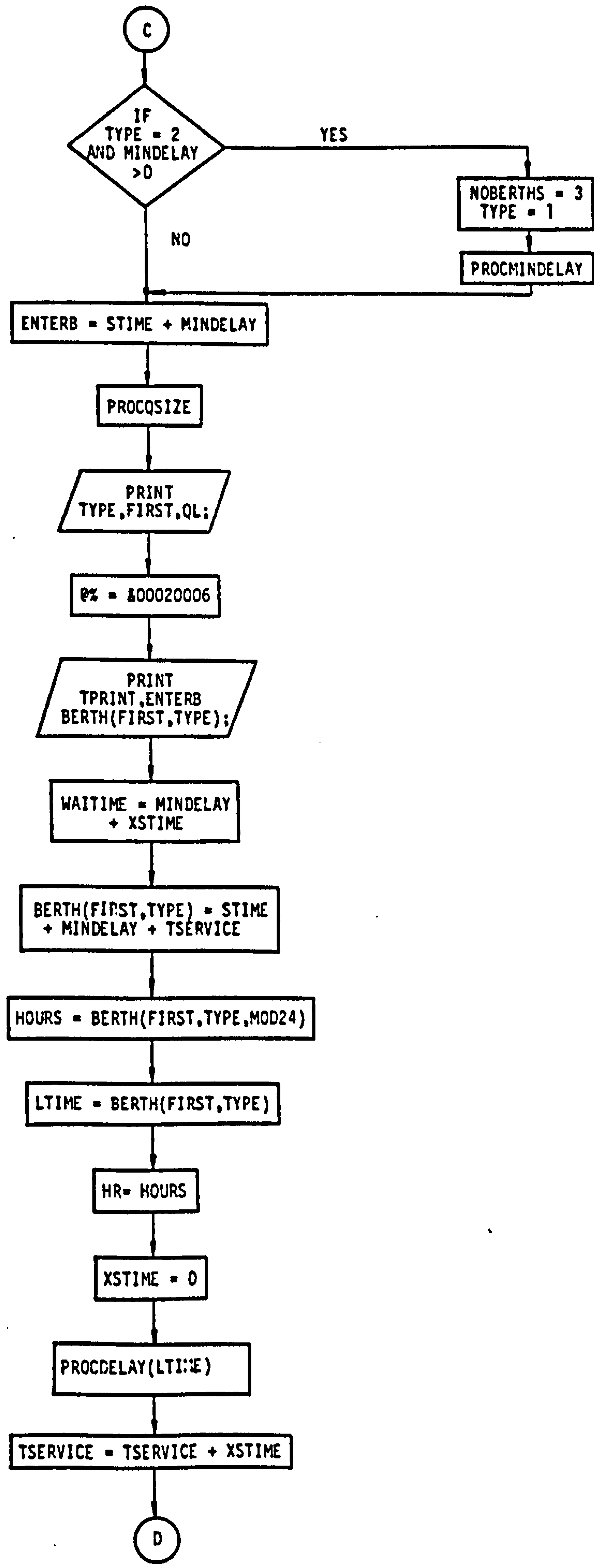
APPENDIX D

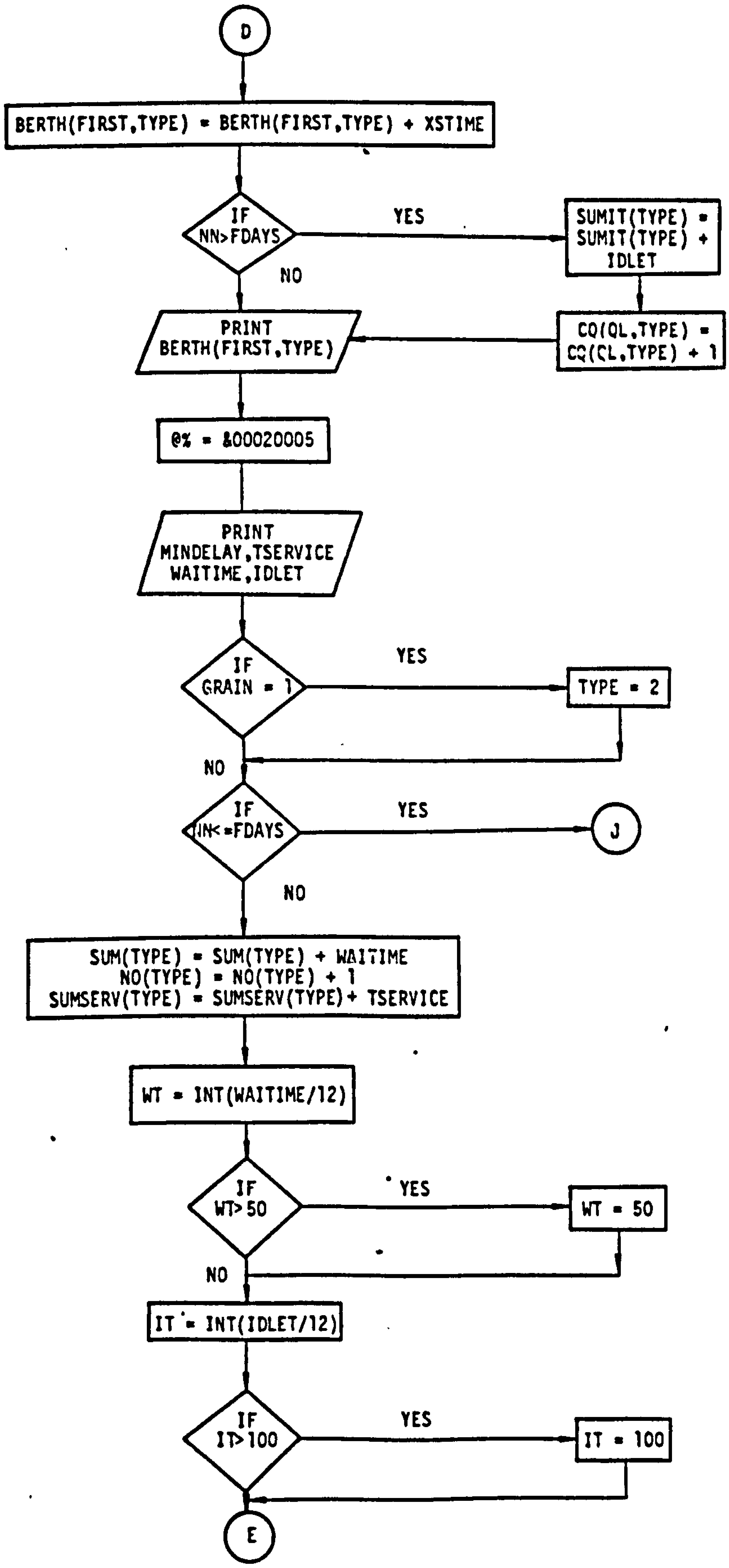
COMPUTER FLOWCHART FOR THE SIMULATION PROGRAMME

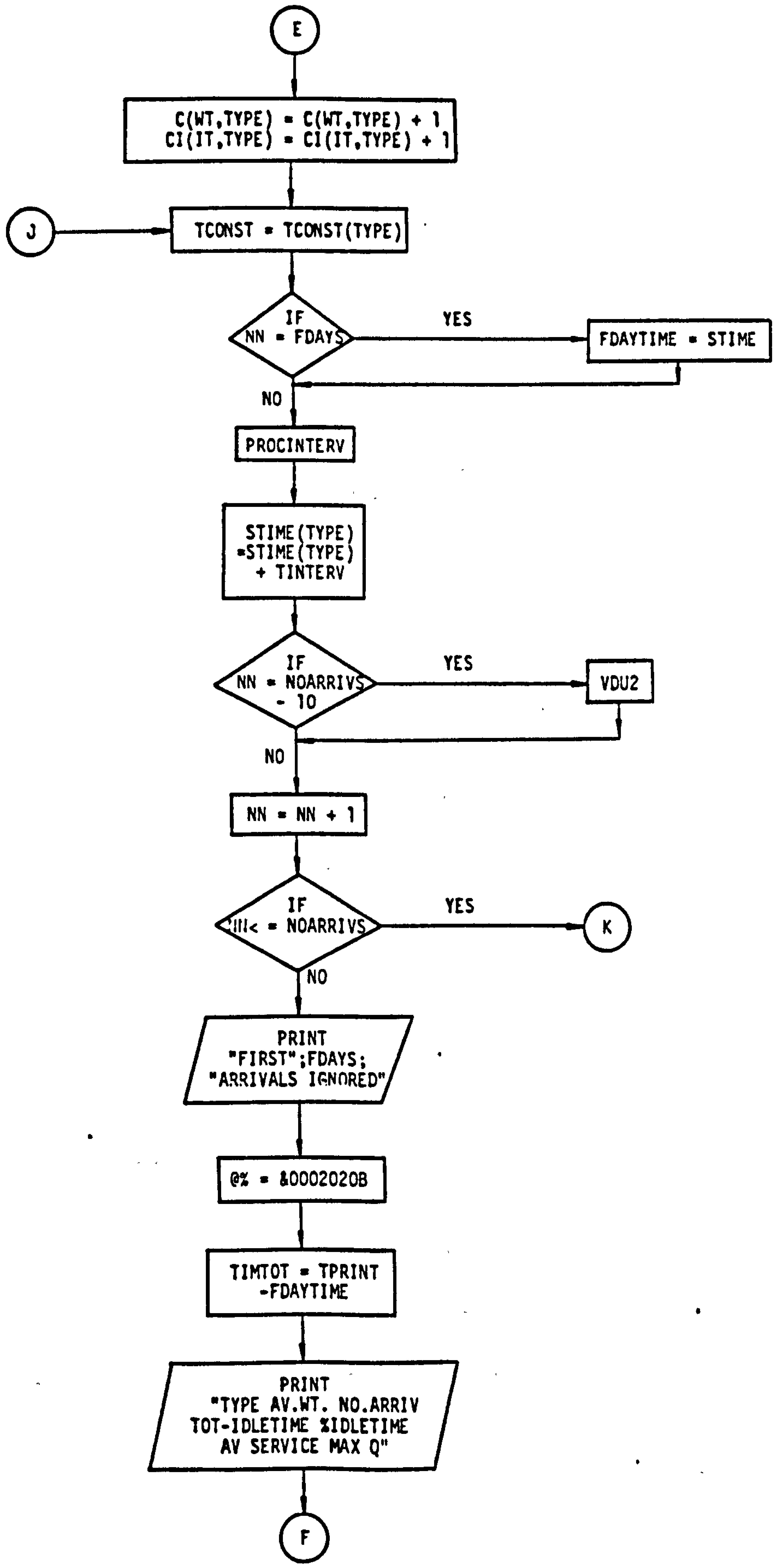

START
R = RND(-1)
ARRAYSZE = 100
TIDE1 = 0
NEWDAYS = -1
DIMENSION SUMSER(4),NUMB(4),STD(4),C(100,4),CI(200,4),
G(ARRAYSZE,4),START(4),FA(4),QUEUE(4),MAXQL(4),CQ(100,4),
AVLOAD(4),AVUNLOAD(4),STIME(4),TCONST(4),NOBERTHS(4)
BERTHS(15,4),TSERV(4),
SUM(4),NO(4),SUMIT(4)
@% = &01000004
PRINT
TYP,DAY,HR,TDE.BTH.BTH;Q;
@% = &01000007
PRINT
ARRIV,ENTER,LEFT,LEAVE,DELAY,
SERV,WAIT,IDLE
NOARRIVS = 1252
FDAYS = 626
NT = 4
NN = 1
FOR T
= 1 TO NT
READ
NOSHIPS
A

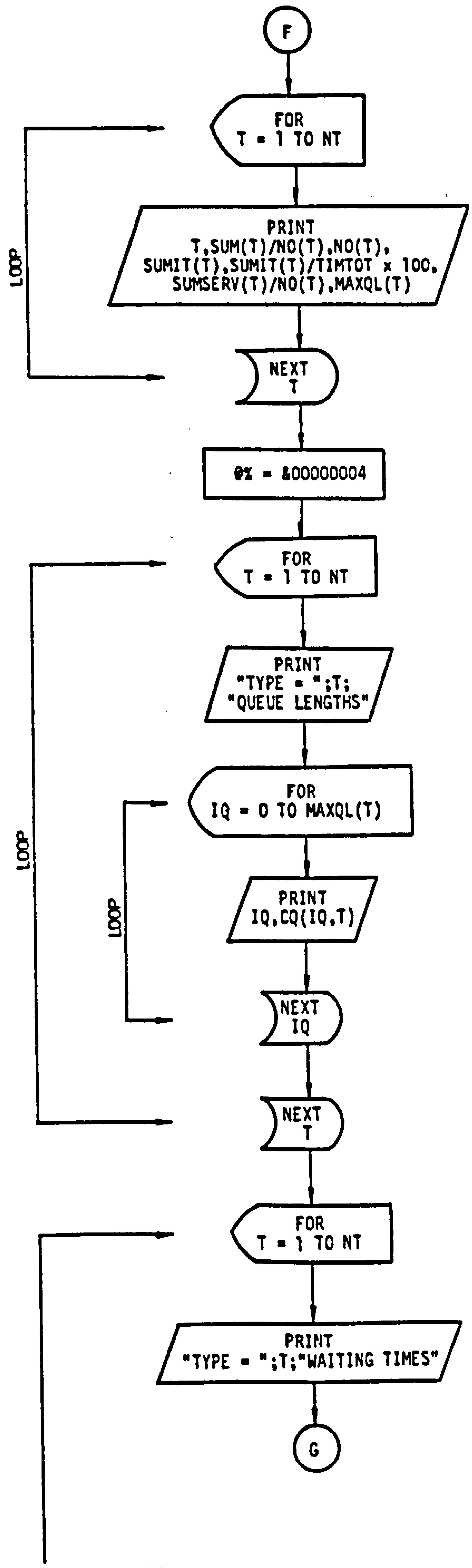

A
TCONST(T) = 365 x 24 / NOSHIPS
READ
NOBERTHS(T),TSERV(T)
STD(T)
NEXT T
LOOP
FOR T = 1 TO NT
TCONST = TCONST(T)
PROCINTERV
MAXQL(T) = 0
QUEUE(T) = TRUE
START(T) = 0
FA(T) = 0
STIME(T) = TINTERV
NEXT T
LOOP
FOR T = 1 TO 3
STIME(T) = 10^6
NO(T) = 1
NUMB(T) = 1
NEXT T
LOOP
K
GRAIN = 0
XSTIME = 0
IDLET = 0
STIME = 10^6
B

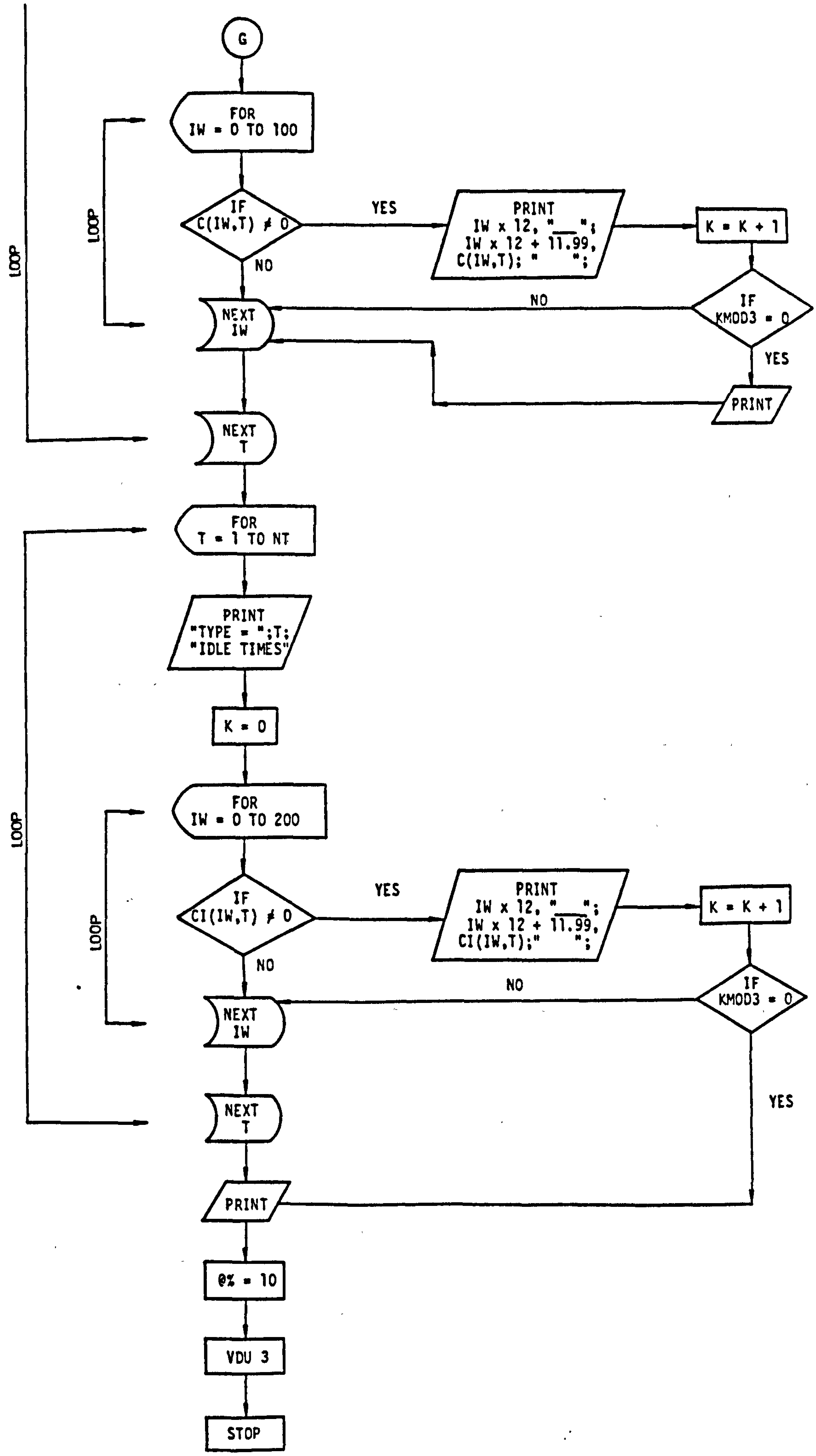

B
FOR
T = 1 TO NT
IF
STIME(T)<STIME
YES
STIME = INT(STIME(T))
TYPE = T
NO
LOOP
NEXT
T
TPRINT = STIME
HOURS = STIMEMOD24
DAYS = STIME/24
HRS = HOURS
PROCDELAY(STIME)
STIME = STIME + XSTIME
PROCNORMAL
NOBERTHS = NOBERTHS(TYPE)
MINDELAY = 100000
@% = &00000004
PRINT
TYPE,DAYS
HRS,XSTIME
PROCMINDELAY
IF
TYPE = 2
YES
GRAIN = 1
NO
C


C
IF TYPE = 2 AND MINDELAY >0
YES
NO
NOBERTHS = 3
TYPE = 1
PROCMINDELAY
ENTERB = STIME + MINDELAY
PROCQSIZE
PRINT TYPE,FIRST,QL;
@% = &00020006
PRINT TPRINT,ENTERB BERTH(FIRST,TYPE);
WAITIME = MINDELAY + XSTIME
BERTH(FIRST,TYPE) = STIME + MINDELAY + TSERVICE
HOURS = BERTH(FIRST,TYPE,MOD24)
LTIME = BERTH(FIRST,TYPE)
HR= HOURS
XSTIME = 0
PROCDELAY(LTIME)
TSERVICE = TSERVICE + XSTIME
D

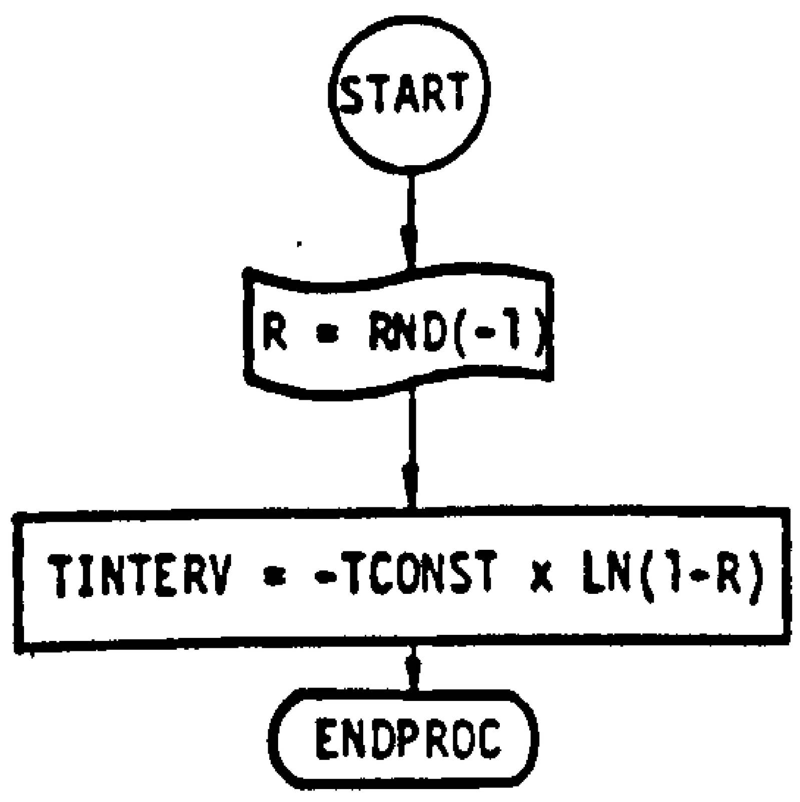

D
BERTH(FIRST,TYPE) = BERTH(FIRST,TYPE) + XSTIME
IF NN>FDAYS
YES
NO
SUMIT(TYPE) = SUMIT(TYPE) + IDLET
CQ(QL,TYPE) = CQ(CL,TYPE) + 1
PRINT BERTH(FIRST,TYPE)
@% = &00020005
PRINT MINDELAY,TSERVICE WAITIME,IDLET
IF GRAIN = 1
YES
TYPE = 2
NO
IF IN<=FDAYS
YES
J
NO
SUM(TYPE) = SUM(TYPE) + WAITIME
NO(TYPE) = NO(TYPE) + 1
SUMSERV(TYPE) = SUMSERV(TYPE)+ TSERVICE
WT = INT(WAITIME/12)
IF WT>50
YES
WT = 50
NO
IT = INT(IDLET/12)
IF IT>100
YES
IT = 100
E


E
C(WT,TYPE) = C(WT,TYPE) + 1
CI(IT,TYPE) = CI(IT,TYPE) + 1
J
TCONST = TCONST(TYPE)
IF NN = FDAYS
YES
FDAYTIME = STIME
NO
PROCINTERV
STIME(TYPE) =STIME(TYPE) + TINTERV
IF NN = NOARRIVS - 10
YES
VDU2
NO
NN = NN + 1
IF NN = NOARRIVS
YES
K
NO
PRINT "FIRST";FDAYS; "ARRIVALS IGNORED"
@% = &0002020B
TIMTOT = TPRINT -FDAYTIME
PRINT "TYPE AV.WT. NO.ARRIV TOT-IDLETIME %IDLETIME AV SERVICE MAX Q"
F

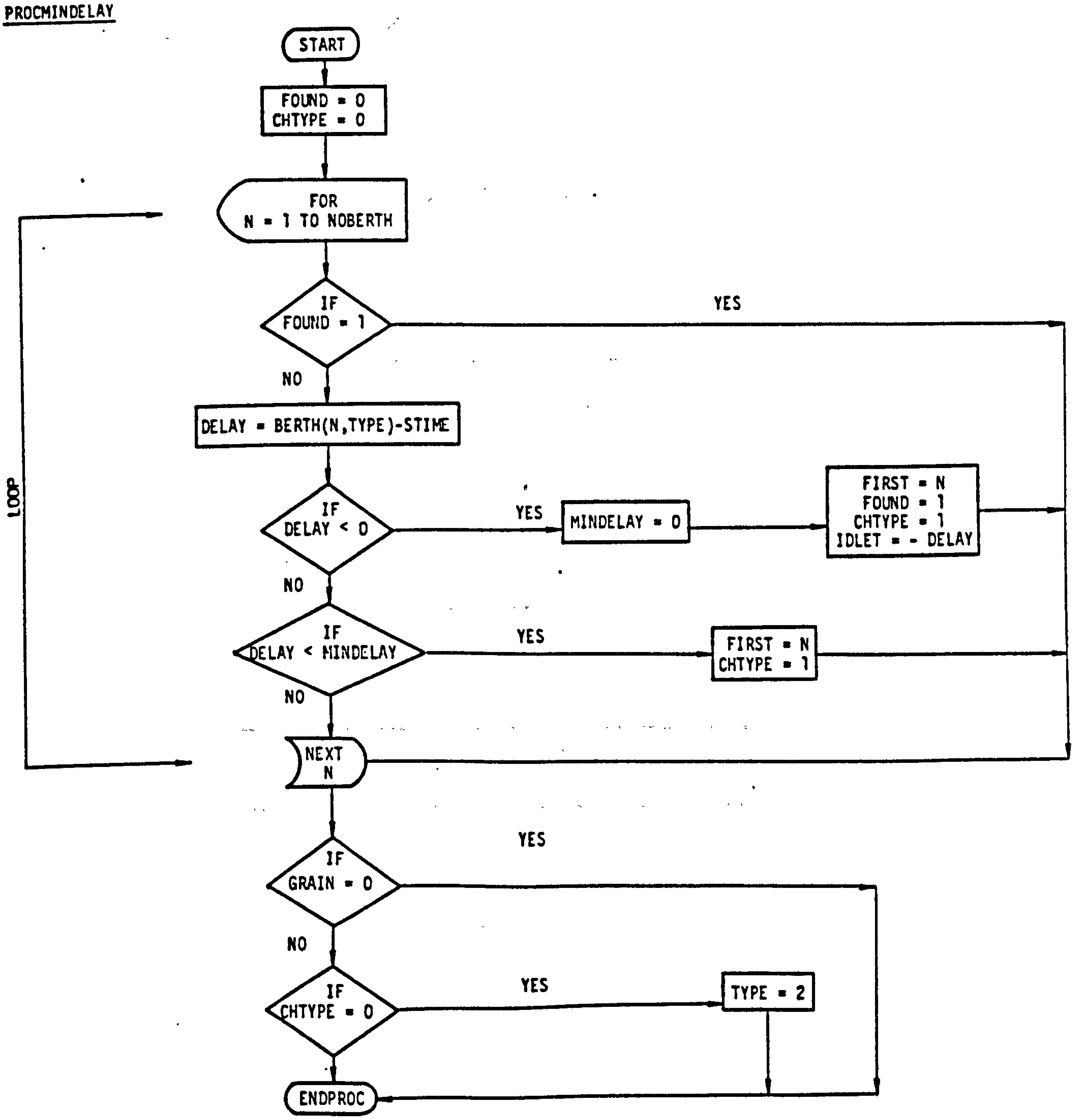

F
FOR
T = 1 TO NT
PRINT
T,SUM(T)/NO(T),NO(T),
SUMIT(T),SUMIT(T)/TIMTOT x 100,
SUMSERV(T)/NO(T),MAXQL(T)
LOOP
NEXT
T
@% = &00000004
FOR
T = 1 TO NT
PRINT
"TYPE = ";T;
"QUEUE LENGTHS"
FOR
IQ = 0 TO MAXQL(T)
PRINT
IQ,CQ(IQ,T)
LOOP
NEXT
IQ
LOOP
NEXT
T
FOR
T = 1 TO NT
PRINT
"TYPE = ";T;"WAITING TIMES"
G


G
FOR
IW = 0 TO 100
LOOP
LOOP
IF
C(IW,T) ≠ 0
YES
PRINT
IW x 12, "___";
IW x 12 + 11.99,
C(IW,T); "   ";
K = K + 1
NO
NEXT
IW
NO
IF
KMOD3 = 0
YES
PRINT
NEXT
T
FOR
T = 1 TO NT
PRINT
"TYPE = ";T;
"IDLE TIMES"
K = 0
LOOP
FOR
IW = 0 TO 200
LOOP
IF
CI(IW,T) ≠ 0
YES
PRINT
IW x 12, "___";
IW x 12 + 11.99,
CI(IW,T);"   ";
K = K + 1
NO
NEXT
IW
NO
IF
KMOD3 = 0
NEXT
T
YES
PRINT
@% = 10
VDU 3
STOP

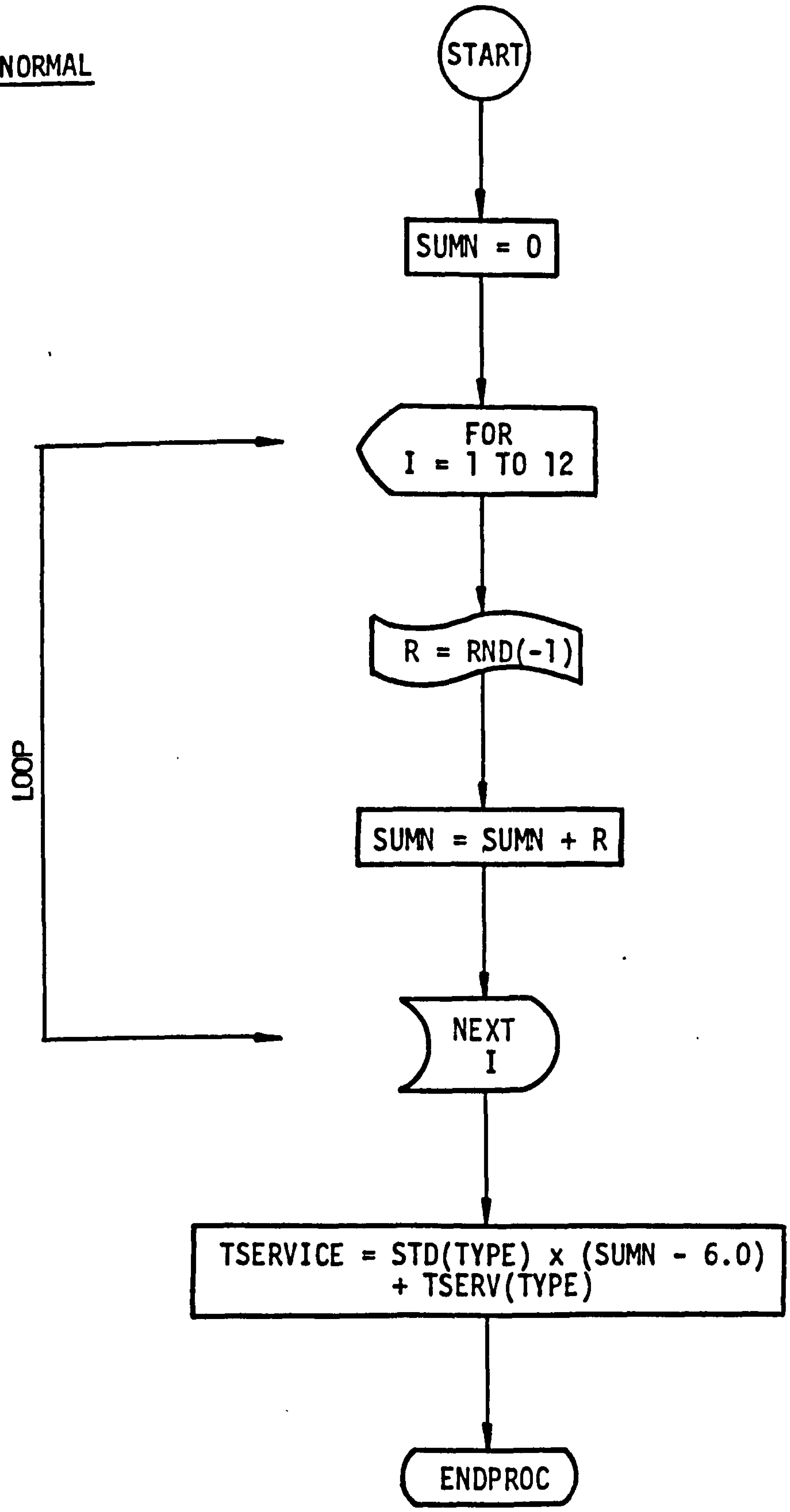
PROCINTERV



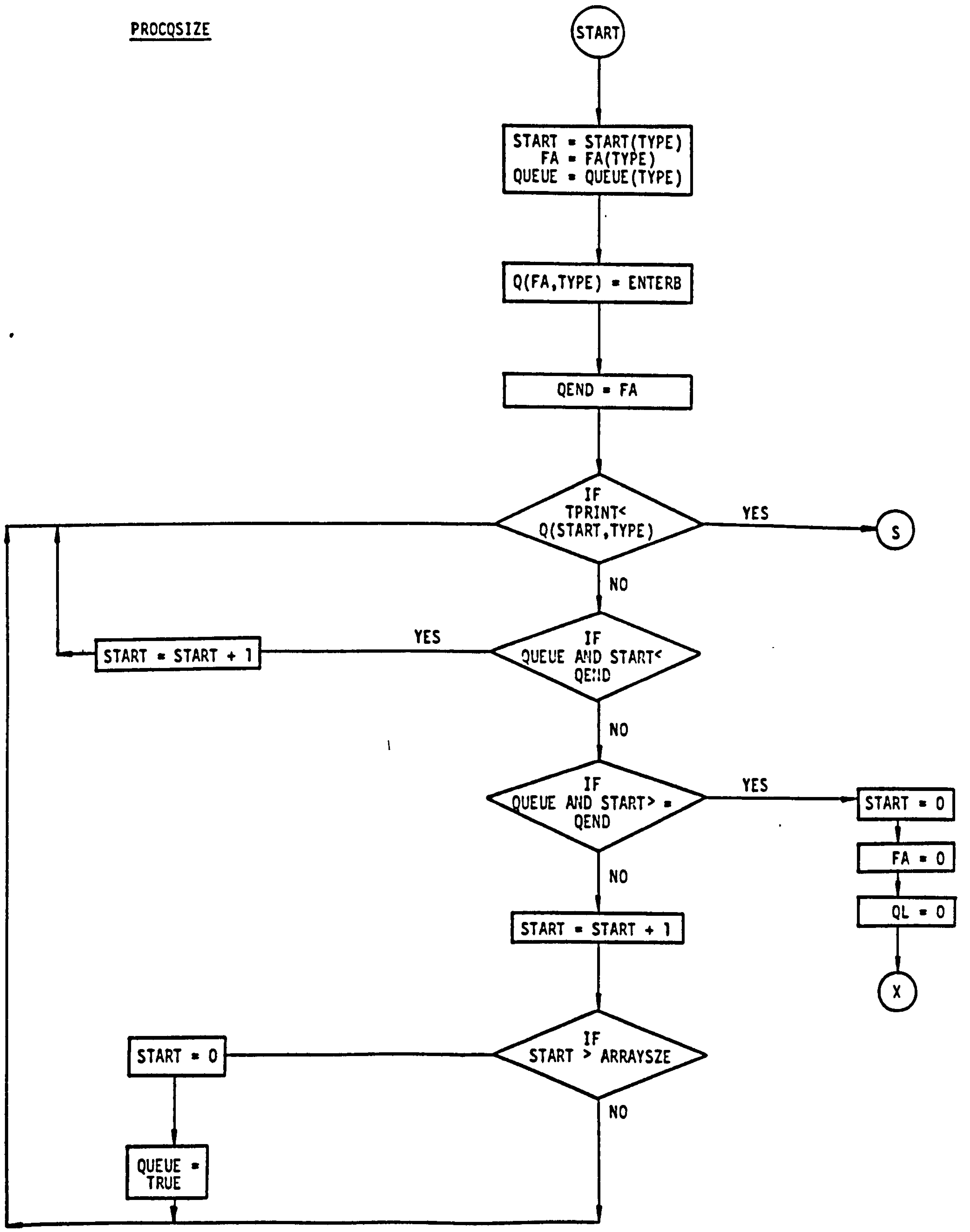
PROCMINDELAY

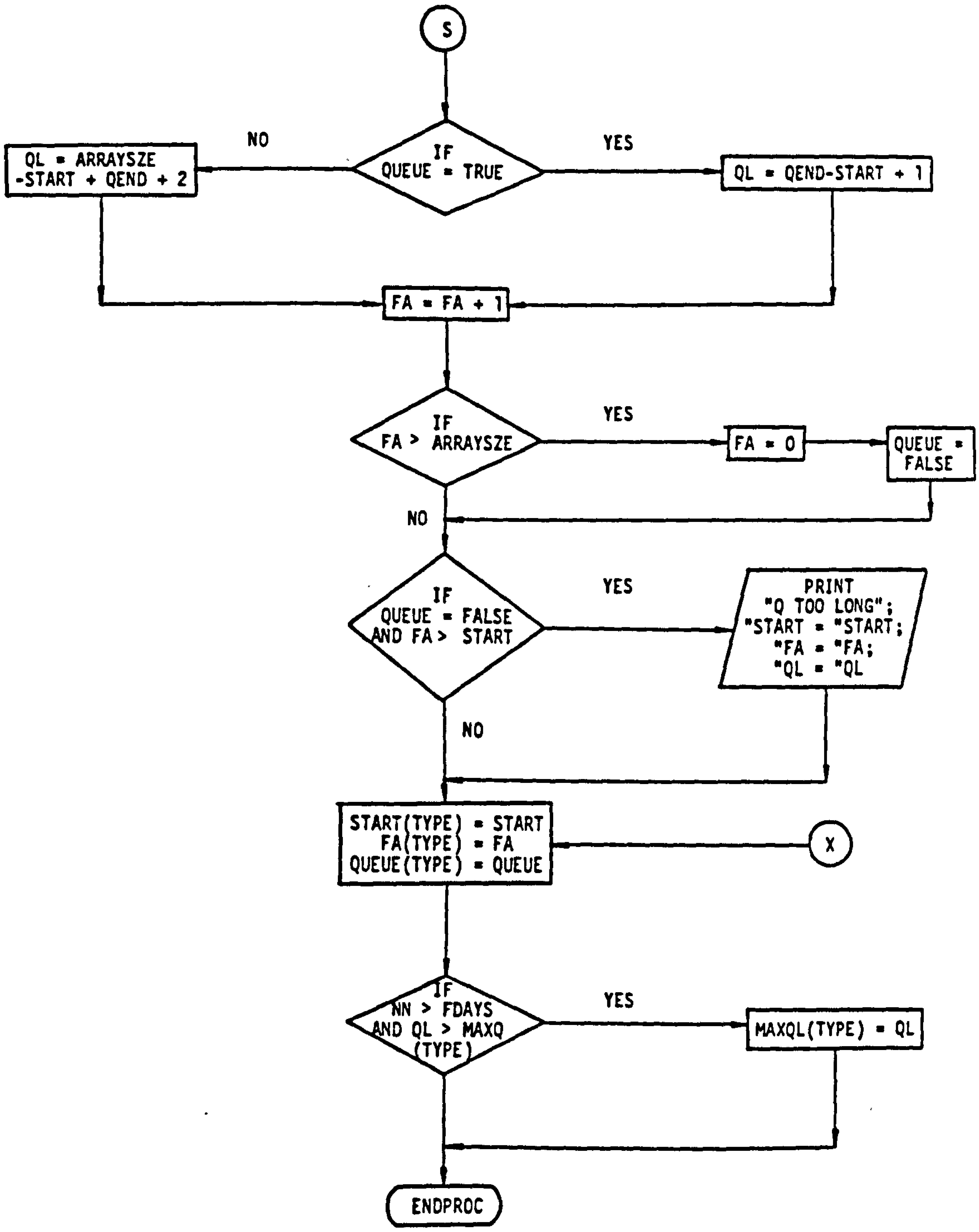


PROCNORMAL

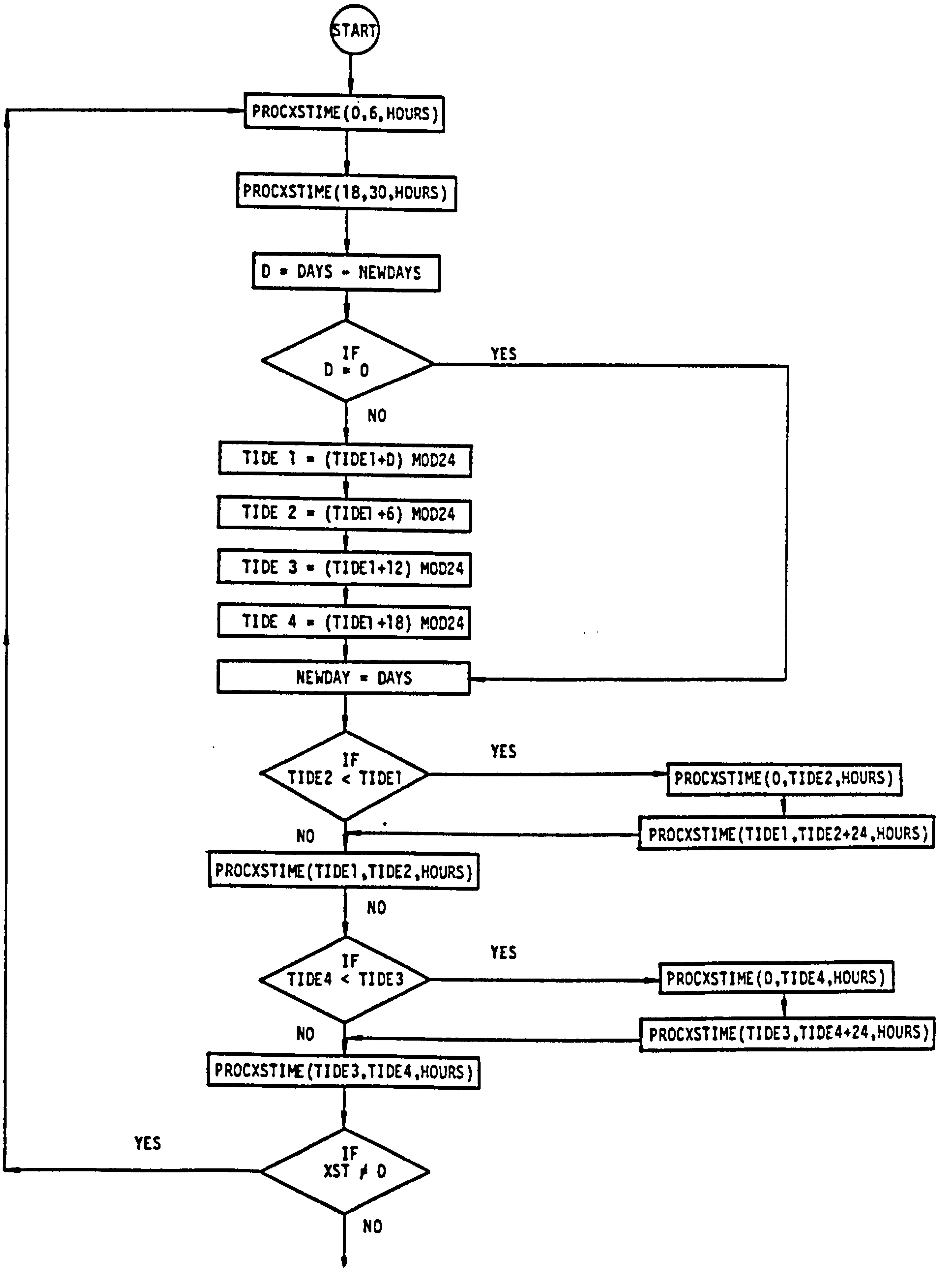

START
SUMN = 0
FOR
I = 1 TO 12
R = RND(-1)
SUMN = SUMN + R
NEXT
I
LOOP
TSERVICE = STD(TYPE) x (SUMN - 6.0)
+ TSERV(TYPE)
ENDPROC

PROCQSIZE

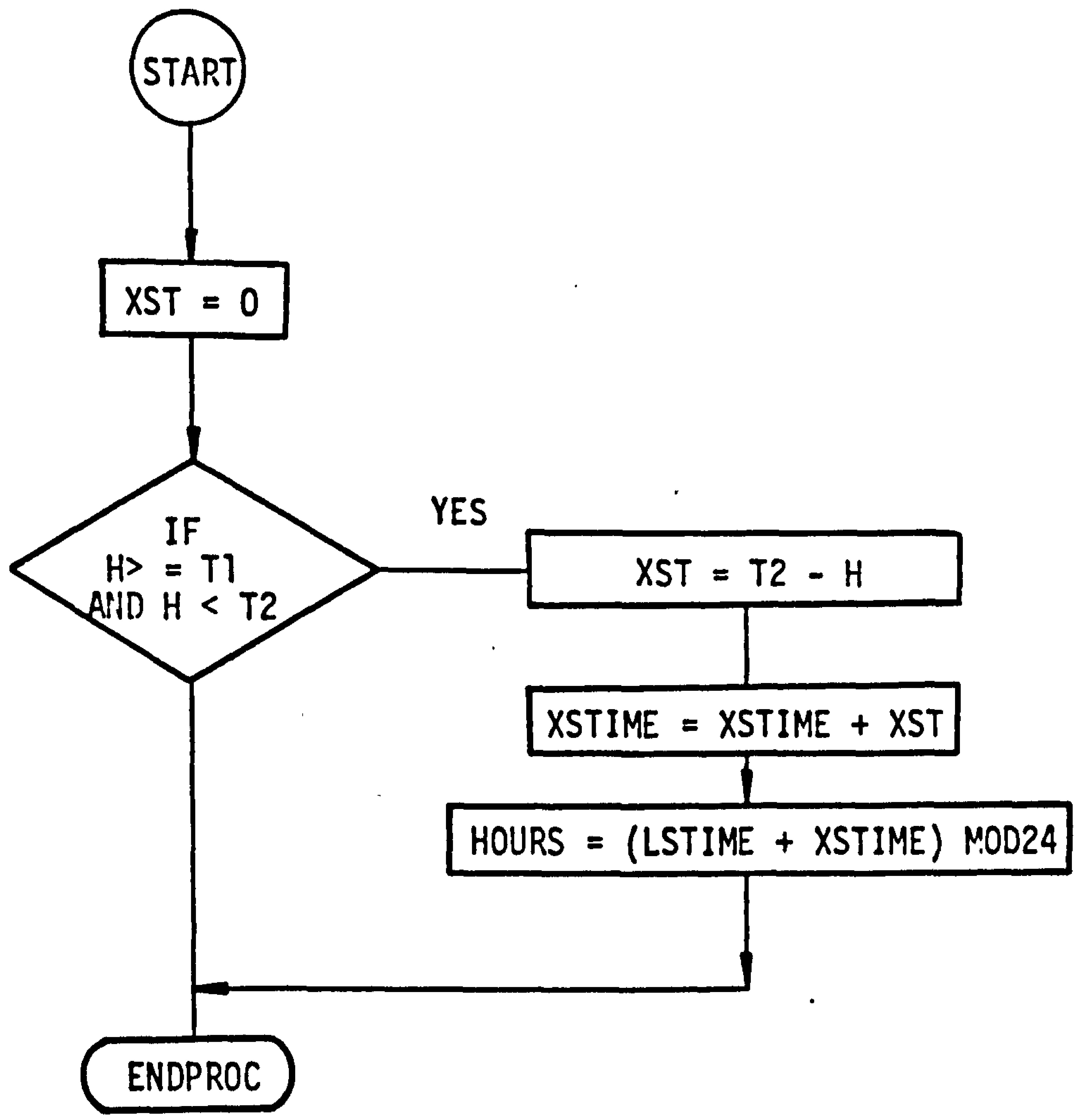

START
START = START(TYPE)
FA = FA(TYPE)
QUEUE = QUEUE(TYPE)
Q(FA,TYPE) = ENTERB
QEND = FA
IF TPRINT< Q(START,TYPE)
YES
S
NO
IF QUEUE AND START< QEND
YES
START = START + 1
NO
IF QUEUE AND START> = QEND
YES
START = 0
FA = 0
QL = 0
X
NO
START = START + 1
IF START > ARRAYSZE
START = 0
QUEUE = TRUE
NO


S
IF
QUEUE = TRUE
NO
YES
QL = ARRAYSZE
-START + QEND + 2
QL = QEND-START + 1
FA = FA + 1
IF
FA > ARRAYSZE
YES
FA = 0
QUEUE =
FALSE
NO
IF
QUEUE = FALSE
AND FA > START
YES
PRINT
"Q TOO LONG";
"START = "START;
"FA = "FA;
"QL = "QL
NO
START(TYPE) = START
FA(TYPE) = FA
QUEUE(TYPE) = QUEUE
X
IF
NN > FDAYS
AND QL > MAXQ
(TYPE)
YES
MAXQL(TYPE) = QL
ENDPROC

PROCDELAY (LSTIME)



PROCXSTIME(T1,T2,H)



APPENDIX E

LISTING OF THE COMPUTER PROGRAMME AND OUTPUT OF THE SIMULATION MODEL

```
>L.0,520
   10 R=RND(-1)
   20 ARRAYSIZE=100:TIDE1=0: NEWDAYS=-1
   30 DIM SUMSERV(4),NUMB(4),STD(4),C(100,4),CI(200,4),Q(ARRAYSIZE,4)
   40 DIM START(4),FA(4),QUEUE(4),MAXQL(4),CQ(100,4)
   50 DIM AVLOAD(4),AVUNLOAD(4),STIME(4),TCONST(4),NOBERTHS(4),BERTH(15,4)
   60 DIM TSERV(4),SUM(4),NO(4),SUMIT(4)
   70 @%=&01000004
   80 PRINT" TYP"," DAY"," HR"," TDE", " BTH"," BTH";" Q ";
   90 @%=&01000007
  100 PRINT  " ARRIV","ENTER","LEFT","LEAVE","DELAY","SERV","WAIT","IDLE"
  110 NOARRIVS=1252
  120 FDAYS=626:NT=4:NN=1
  130 FOR T=1 TO NT:READ NOSHIPS:TCONST(T)=365*24/NOSHIPS
  140READ NOBERTHS(T),TSERV(T),STD(T):NEXTT
  150    REM***CALC.TIMEINTERVAL CONSTANT FOR EACH SHIP
  160 FOR T=1 TO NT:TCONST=TCONST(T):PROCINTERV
  170    REM***CALC TIME OF FIRST SHIP OF EACH TYPE.
  180 MAXQL(T)=0:QUEUE(T)=TRUE:START(T)=0: FA(T)=0
  190 STIME(T)=TINTERV:NEXT
  200   REM***FIND EARLIEST SHIP.
  210 GOTO220:FOR T=1 TO 3:STIME(T)=10^6:NO(T)=1:NUMB(T)=1 :NEXTT
  220 GRAIN=0: XSTIME=0:IDLET=0: STIME=10^6:FOR T=1 TO NT
  230IF STIME(T)<STIME THENSTIME=INT(STIME(T)):TYPE=T
  240 NEXT T:TPRINT=STIME
  250 HOURS=STIME MOD 24: DAYS=STIME DIV 24 :HRS=HOURS
  260 PROCDELAY(STIME)
  290 STIME=STIME+XSTIME
  300   REM*** CALC TIME TO LOAD & UNLOAD.
  310 PROCNORMAL
  320 NOBERTH=NOBERTHS(TYPE):MINDELAY=100000
  330 @%=&00000004
  340 PRINT  TYPE,DAYS,HRS,XSTIME;
  350 PROCMINDELAY
  360 IF TYPE=2 THEN GRAIN=1
  370 IF TYPE=2 AND MINDELAY>0 THEN NOBERTH=3:TYPE=1:PROCMINDELAY
  380 ENTERB=STIME+MINDELAY:PROCQSIZE :PRINT TYPE,FIRST,QL;
  390 @%=&00020006:PRINT TPRINT,ENTERB,BERTH(FIRST,TYPE);
  400 WAITIME=MINDELAY+XSTIME
  410
  420 BERTH(FIRST,TYPE)=STIME+MINDELAY+TSERVICE :HOURS=BERTH(FIRST,TYPE) MOD 24: LTIME=BERTH(FIRST,TYPE)
  425 HR=HOURS
  430 XSTIME=0: PROCDELAY(LTIME)
  440 TSERVICE=TSERVICE+XSTIME: BERTH(FIRST,TYPE)=BERTH(FIRST,TYPE)+XSTIME
  450 IF NN>FDAYS THEN SUMIT(TYPE)=SUMIT(TYPE)+IDLET:CQ(QL,TYPE)= CQ(QL,TYPE)+1
  460 PRINT BERTH(FIRST,TYPE);"  ";
  470 @%=&00020005:PRINT MINDELAY,TSERVICE,WAITIME,IDLET
  480 IF GRAIN=1 THEN TYPE=2
  490 IF NN<=FDAYS GOTO 530
  500 SUM(TYPE)=SUM(TYPE)+WAITIME :NO(TYPE)=NO(TYPE)+1 : SUMSERV(TYPE)=SUMSERV(TYPE)+TSERVICE:WT=INT(WAITIME/12):IF WT>50 THEN WT=50
  510 IT=INT(IDLET/12):IF IT>100 THEN IT=100
  520 C(WT,TYPE)=C(WT,TYPE)+1:CI(IT,TYPE)=CI(IT,TYPE)+1
```

```
>L.5301,1020
  530 TCONST=TCONST(TYPE)
  540 IF NN=FDAYS THEN FDAYTIME=STIME
  550 PROCINTERV
  560 STIME(TYPE)=STIME(TYPE)+TINTERV
  570 IF NN=NOARRIVS-10 THEN VDU2
  580 NN=NN+1:IF NN<=NOARRIVS GOTO220
  590PRINT' "FIRST ";FDAYS;" ARRIVALS IGNORED."
  600 @%=&0002020B :TIMTOT=TPRINT-FDAYTIME
  610 PRINT "        TYPE   AV.WT.     NO.ARRIV.   TOT.IDLETIME %IDLE TIME AV SERVICE  MAXQ"
  620 FOR T=1 TO NT:PRINTT,SUM(T)/NO(T),NO(T),SUMIT(T),SUMIT(T)/TIMTOT*100,SUMSERV(T)/NO(T),MAXQL(T)
  630 NEXT T
  640 @%=&00000004
  645 FOR T=1 TO NT :PRINT ''TYPE=";T;" QUEUE LENGTHS"
  647 FOR IQ=0 TO MAXQL(T) :PRINT IQ,CQ(IQ,T)
  648 NEXT IQ: NEXT T
  650 FOR T=1 TO NT :PRINT'"TYPE=";T ;" WAITING TIMES"
  660 FOR IW=0 TO 100
  670 IF C(IW,T)<>0 PRINTIW*12;"-";IW*12+11.99,C(IW,T);"      ";:K=K+1:IF K MOD 3=0 PRINT
  680 NEXT IW
  690 NEXT T
  700 FOR T=1 TO NT :PRINT'"TYPE=";T; " IDLE TIMES"
  710 K=0:FOR IW=0 TO 200
  720 IF CI(IW,T)<>0 PRINT IW*12;"-";IW*12+11.99,CI(IW,T);"      ";:K=K+1:IF K MOD 3=0 THENPRINT
  730 NEXT:NEXT  :PRINT
  740 @%=10:VDU3:STOP
  750 DEF PROCINTERV
  760 R=RND(1)
  770 TINTERV=-TCONST*LN(1-R)
  780 ENDPROC
  790 DEF PROCMINDELAY
  800 FOUND=0 :CHTYPE=0
  810   REM***CHECK ALL BERTHS OF THIS TYPE.
  820 FOR N=1 TO NOBERTH
  830 IF FOUND=1 GOTO 870
  840 DELAY=BERTH(N,TYPE)-STIME
  850 IF DELAY<0 THEN MINDELAY=0 :FIRST=N :FOUND=1:CHTYPE=1:IDLET=-DELAY:GOTO870
  860 IF DELAY<MINDELAY THEN MINDELAY=DELAY:FIRST=N:CHTYPE=1
  870 NEXT N
  880 IF GRAIN=0 THEN ENDPROC
  890 IF CHTYPE=0 THEN TYPE=2
  900 ENDPROC
  940 DEF PROCNORMAL
  950 SUMN=0:FOR I=1 TO 12:R=RND(1)
  960 SUMN=SUMN+R:NEXT I
  970 TSERVICE=STD(TYPE)*(SUMN-6.0)+TSERV(TYPE)
  980 ENDPROC
  990 DEF PROCQSIZE
 1000 START=START(TYPE):FA=FA(TYPE):QUEUE=QUEUE(TYPE)
 1010 Q(FA,TYPE)=ENTERB
 1020 QEND=FA
```

```
>L.1030,2000
 1040 IF TPRINT<Q(START,TYPE) GOTO 1070
 1050 IF QUEUE AND START<QEND THEN START=START+1 :GOTO 1040
 1055 IF QUEUE AND START>=QEND THEN START=0 :  FA=0:QL=0:GOTO 1160
 1060 START=START+1
 1062 IF START>ARRAYSZE THEN START=0:QUEUE=TRUE
 1064 GOTO 1040
 1070 IF QUEUE THEN QL=QEND-START+1 ELSE QL=ARRAYSZE-START+QEND+2
 1080 FA=FA+1
 1090 IF FA>ARRAYSZE THEN FA=0:QUEUE=FALSE
 1110 IF QUEUE=FALSE AND FA>START THEN PRINT"Q TOO LONG";" START="START;" FA=";FA ;" QL=";QL
 1160 START(TYPE)=START:FA(TYPE)=FA:QUEUE(TYPE)=QUEUE
 1170 IF NN>FDAYS AND QL>MAXQL(TYPE) THEN MAXQL(TYPE)=QL
 1180 ENDPROC
 1190 DATA 491,15,156,40
 1200 DATA 81,2,435,100
 1210 DATA 15,1,200,60
 1220 DATA 39,1,155,34
 1490 DEF  PROCDELAY(LSTIME)
 1500 PROCXSTIME(0,6,HOURS):PROCXSTIME(18,30,HOURS)
 1510 D=DAYS-NEWDAYS :IF D=0 GOTO 1560
 1520 TIDE1=(TIDE1+D) MOD 24
 1530 TIDE2=(TIDE1+6) MOD 24
 1540 TIDE3=(TIDE1+12) MOD 24
 1550 TIDE4=(TIDE1+18) MOD 24
 1560 NEWDAYS=DAYS
 1570 IF TIDE2<TIDE1 THEN PROCXSTIME(0,TIDE2,HOURS): PROCXSTIME(TIDE1,TIDE2+24,HOURS)ELSE PROCXSTIME(TIDE1,TIDE2,HOURS)
 1580 IF TIDE4<TIDE3 THEN PROCXSTIME(0,TIDE4,HOURS):PROCXSTIME(TIDE3,TIDE4+24,HOURS) ELSE PROCXSTIME(TIDE3,TIDE4,HOURS)
 1590 IF XST<>0 GOTO 1500
 1600 ENDPROC
 1610  DEF PROCXSTIME(T1,T2,H)
 1620 XST=0
 1630 IF H>=T1 AND H<T2 THEN XST=T2-H :XSTIME=XSTIME+XST :HOURS=(LSTIME+XSTIME) MOD 24
 1640 ENDPROC
```

>RUN

TYPE	DAY	HR	TDE	BTH	BTH	Q	ARRIV	ENTER	LEFT	LEAVE	DELAY	SERV	WAIT	IDL
3	0	1	6	3	1	1	1.	7.	0.	199.	0.	192.	6.	7.
3	2	11	0	3	1	1	59.	199.	199.	346.	140.	146.	140.	0.
1	4	3	8	1	1	1	99.	107.	0.	251.	0.	144.	8.	107.
1	5	14	0	1	2	0	134.	134.	0.	349.	0.	215.	0.	134.
1	6	7	6	1	3	1	151.	157.	0.	374.	0.	217.	6.	157.
4	6	12	1	4	1	1	156.	157.	0.	254.	0.	97.	1.	157.
1	6	19	11	1	4	1	163.	174.	0.	305.	0.	131.	11.	174.
1	8	14	1	1	5	1	206.	207.	0.	390.	0.	183.	1.	207.
1	9	9	0	1	6	0	225.	225.	0.	329.	0.	104.	0.	225.
1	9	18	12	1	7	1	234.	246.	0.	367.	0.	121.	12.	246.
3	9	18	12	3	1	1	234.	346.	346.	487.	100.	141.	112.	0.
1	9	19	11	1	8	2	235.	246.	0.	328.	0.	82.	11.	246.
1	11	6	0	1	1	0	270.	270.	251.	390.	0.	120.	0.	19.
1	12	16	3	1	4	1	304.	307.	305.	439.	0.	132.	3.	2.
1	13	1	7	1	9	1	313.	320.	0.	464.	0.	144.	7.	320.
1	15	17	5	1	2	1	377.	382.	349.	490.	0.	108.	5.	33.
2	16	5	6	2	1	1	389.	395.	0.	779.	0.	384.	6.	395.
4	16	11	0	4	1	0	395.	395.	254.	563.	0.	168.	0.	141.
1	16	15	0	1	1	0	399.	399.	390.	563.	0.	164.	0.	9.
1	16	16	0	1	3	0	400.	400.	374.	588.	0.	188.	0.	26.
1	18	19	11	1	4	1	451.	462.	439.	655.	0.	193.	11.	23.
2	19	7	0	2	2	0	463.	463.	0.	943.	0.	480.	0.	463.
1	19	8	6	1	5	1	464.	470.	390.	615.	0.	145.	6.	80.
2	19	20	10	1	2	1	476.	490.	490.	808.	4.	317.	14.	0.
1	20	3	3	1	6	2	483.	486.	329.	655.	0.	169.	3.	157.
1	21	3	3	1	7	1	507.	510.	367.	713.	0.	203.	3.	143.
1	21	19	11	1	8	1	523.	534.	328.	688.	0.	154.	11.	206.
1	22	4	2	1	9	2	532.	534.	464.	679.	0.	145.	2.	70.
1	22	4	2	1	10	3	532.	534.	0.	703.	0.	169.	2.	534.
2	22	10	0	1	1	1	538.	563.	563.	1002.	25.	439.	25.	0.
1	22	14	3	1	11	2	542.	545.	0.	703.	0.	158.	3.	545.
1	24	14	17	1	3	1	590.	607.	588.	800.	0.	193.	17.	19.
1	24	17	14	1	12	2	593.	607.	0.	704.	0.	97.	14.	607.
1	25	7	1	1	13	1	607.	608.	0.	826.	0.	218.	1.	608.
1	25	15	17	1	5	1	615.	632.	615.	801.	0.	169.	17.	17.
2	27	12	0	2	1	1	660.	779.	779.	1190.	119.	410.	119.	0.
2	28	3	8	1	3	1	675.	800.	800.	1235.	117.	436.	125.	0.
1	29	7	5	1	4	2	703.	708.	655.	950.	0.	242.	5.	53.
4	29	9	3	4	1	1	705.	708.	563.	804.	0.	96.	3.	145.
1	31	22	8	1	6	3	766.	774.	655.	943.	0.	169.	8.	119.
1	32	13	2	1	7	4	781.	783.	713.	943.	0.	160.	2.	70.
1	32	19	11	1	8	5	787.	798.	688.	942.	0.	144.	11.	110.
1	33	19	11	1	2	1	811.	822.	808.	991.	0.	169.	11.	14.
1	33	21	9	1	5	2	813.	822.	801.	991.	0.	169.	9.	21.
1	33	23	7	1	9	3	815.	822.	679.	1014.	0.	192.	7.	143.
1	34	9	0	1	10	0	825.	825.	703.	906.	0.	81.	0.	122.
1	35	13	5	1	11	1	853.	858.	703.	1041.	0.	183.	5.	155.
1	35	23	7	1	12	1	863.	870.	704.	1086.	0.	216.	7.	166.
1	36	1	6	1	13	2	865.	871.	826.	1004.	0.	133.	6.	45.
1	36	3	4	1	14	3	867.	871.	0.	1112.	0.	241.	4.	871.
2	36	20	11	2	2	1	884.	943.	943.	1381.	48.	438.	59.	0.
1	36	22	9	1	15	1	886.	895.	0.	1115.	0.	220.	9.	895.
1	37	13	0	1	10	1	901.	906.	906.	1041.	5.	135.	5.	0.
1	38	1	8	1	8	1	913.	942.	942.	1139.	21.	197.	29.	0.
1	38	15	6	1	6	2	927.	943.	943.	1137.	10.	195.	16.	0.
1	39	9	1	1	7	1	945.	946.	943.	1127.	0.	181.	1.	3.
1	40	8	3	1	4	1	968.	971.	950.	1115.	0.	144.	3.	21.
1	42	19	11	1	1	1	1027.	1038.	1002.	1206.	0.	168.	11.	36.
2	42	21	9	1	2	2	1029.	1038.	991.	1447.	0.	409.	9.	47.

2	42	22	8	2	1	1	1030.	1190.	1190.	1669.	152.	480.	160.	0.
1	43	0	6	1	5	3	1032.	1038.	991.	1214.	0.	176.	6.	47.
3	43	10	4	3	1	1	1042.	1046.	487.	1207.	0.	161.	4.	559.
2	44	4	2	1	1	1	1060.	1206.	1206.	1614.	144.	408.	146.	0.
1	46	5	1	1	9	2	1109.	1110.	1014.	1207.	0.	97.	1.	96.
2	46	12	5	1	3	3	1116.	1235.	1235.	1855.	114.	619.	119.	0.
1	46	15	2	1	4	4	1119.	1121.	1115.	1242.	0.	121.	2.	6.
1	47	8	0	1	7	5	1136.	1136.	1127.	1303.	0.	167.	0.	9.
1	47	20	10	1	6	6	1148.	1158.	1137.	1304.	0.	146.	10.	21.
4	48	16	15	4	1	1	1168.	1183.	804.	1303.	0.	120.	15.	379.
1	49	6	2	1	8	7	1182.	1184.	1139.	1331.	0.	147.	2.	45.
1	50	11	0	1	9	6	1211.	1211.	1207.	1353.	0.	142.	0.	4.
1	50	12	0	1	10	7	1212.	1212.	1041.	1335.	0.	123.	0.	171.
1	50	15	18	1	5	8	1215.	1233.	1214.	1359.	0.	126.	18.	19.
1	50	21	12	1	11	9	1221.	1233.	1041.	1356.	0.	123.	12.	192.
1	50	23	10	1	12	10	1223.	1233.	1086.	1378.	0.	145.	10.	147.
1	51	3	7	1	13	11	1227.	1234.	1004.	1451.	0.	217.	7.	230.
1	51	9	1	1	14	12	1233.	1234.	1112.	1378.	0.	144.	1.	122.
4	52	7	4	4	1	1	1255.	1303.	1303.	1451.	44.	148.	48.	0.
1	52	16	0	1	4	0	1264.	1264.	1242.	1451.	0.	187.	0.	22.
1	53	9	3	1	15	1	1281.	1284.	1115.	1477.	0.	193.	3.	169.
1	53	15	0	1	7	1	1287.	1303.	1303.	1548.	16.	246.	16.	0.
1	54	1	5	1	6	2	1297.	1304.	1304.	1477.	2.	173.	7.	0.
4	54	4	2	4	1	2	1300.	1451.	1451.	1591.	149.	139.	151.	0.
1	54	16	0	1	8	1	1312.	1331.	1331.	1471.	19.	140.	19.	0.
1	54	21	9	1	10	2	1317.	1335.	1335.	1478.	9.	143.	18.	0.
1	57	11	5	1	5	1	1379.	1384.	1359.	1567.	0.	183.	5.	25.
1	57	17	0	1	9	0	1385.	1385.	1353.	1591.	0.	206.	0.	32.
1	58	16	1	1	11	1	1408.	1409.	1356.	1543.	0.	134.	1.	53.
1	58	22	8	1	12	1	1414.	1422.	1378.	1625.	0.	203.	8.	44.
1	59	15	3	1	14	1	1431.	1434.	1378.	1602.	0.	168.	3.	56.
1	59	19	11	1	2	1	1435.	1447.	1447.	1543.	1.	96.	12.	0.
1	60	3	4	1	13	2	1443.	1451.	1451.	1567.	4.	116.	8.	0.
1	60	9	0	1	4	2	1449.	1451.	1451.	1593.	2.	142.	2.	0.
2	61	2	6	2	2	1	1466.	1472.	1381.	1765.	0.	293.	6.	91.
1	61	8	0	1	8	0	1472.	1472.	1471.	1664.	0.	192.	0.	1.
1	61	20	12	1	6	1	1484.	1496.	1477.	1640.	0.	144.	12.	19.
1	61	21	11	1	10	2	1485.	1496.	1478.	1640.	0.	144.	11.	18.
1	63	17	5	1	15	1	1529.	1534.	1477.	1714.	0.	180.	5.	57.
1	64	1	10	1	2	1	1537.	1547.	1543.	1716.	0.	169.	10.	4.
1	64	7	4	1	11	2	1543.	1547.	1543.	1704.	0.	157.	4.	4.
1	65	15	0	1	5	0	1575.	1575.	1567.	1693.	0.	118.	0.	8.
1	65	22	14	1	4	1	1582.	1596.	1593.	1696.	0.	100.	14.	3.
4	66	11	2	4	1	1	1595.	1597.	1591.	1790.	0.	193.	2.	6.
2	66	12	1	1	1	1	1596.	1614.	1614.	2023.	17.	408.	18.	0.
2	66	18	12	2	1	1	1602.	1669.	1669.	2070.	55.	401.	67.	0.
1	67	0	6	1	7	2	1608.	1614.	1548.	1794.	0.	180.	6.	66.
2	67	7	0	1	2	1	1615.	1716.	1716.	2102.	101.	387.	101.	0.
1	68	13	2	1	6	2	1645.	1647.	1640.	1912.	0.	265.	2.	7.
2	68	23	7	2	2	2	1655.	1765.	1765.	2311.	103.	546.	110.	0.
1	69	21	9	1	8	3	1677.	1686.	1664.	1865.	0.	179.	9.	22.
1	69	22	8	1	9	4	1678.	1686.	1591.	1831.	0.	145.	8.	95.
1	70	2	4	1	10	5	1682.	1686.	1640.	1831.	0.	145.	4.	46.
1	70	15	2	1	4	6	1695.	1697.	1696.	1841.	0.	144.	2.	1.
1	71	20	10	1	5	1	1724.	1734.	1693.	1902.	0.	168.	10.	41.
4	72	14	17	4	1	1	1742.	1790.	1790.	1928.	31.	138.	48.	0.
2	73	11	0	1	3	1	1763.	1855.	1855.	2313.	92.	458.	92.	0.
2	74	4	5	1	1	2	1780.	2023.	2023.	2505.	238.	483.	243.	0.
2	74	10	0	2	1	1	1786.	2070.	2070.	2578.	284.	508.	284.	0.
1	74	23	10	1	7	3	1799.	1809.	1794.	2001.	0.	192.	10.	15.
1	75	8	2	1	11	4	1808.	1810.	1704.	1930.	0.	120.	2.	106.
1	75	14	0	1	12	5	1814.	1814.	1625.	2002.	0.	188.	0.	189.
1	75	20	14	1	9	6	1820.	1834.	1831.	2026.	0.	192.	14.	3.
4	76	7	4	4	1	1	1831.	1928.	1928.	2123.	93.	195.	97.	0.
1	76	11	0	1	10	7	1835.	1835.	1831.	2027.	0.	192.	0.	4.
1	77	10	2	1	4	7	1858.	1860.	1841.	2030.	0.	170.	2.	19.

4	77	16	0	4	1	2	1864.	2123.	2123.	2295.	259.	172.	259.	0.
1	78	0	6	1	8	8	1872.	1878.	1865.	1957.	0.	79.	6.	13.
1	79	2	4	1	13	9	1898.	1902.	1567.	2022.	0.	120.	4.	335.
1	79	2	4	1	14	10	1898.	1902.	1602.	2046.	0.	144.	4.	300.
1	79	3	3	1	15	11	1899.	1902.	1714.	2070.	0.	168.	3.	188.
1	79	14	0	1	5	12	1910.	1910.	1902.	2054.	0.	144.	0.	8.
1	79	17	0	1	6	13	1913.	1913.	1912.	2046.	0.	133.	0.	1.
2	80	8	0	1	2	14	1928.	2102.	2102.	2527.	174.	424.	174.	0.
1	81	4	2	1	11	15	1948.	1950.	1930.	2119.	0.	169.	2.	20.
1	83	12	6	1	7	16	2004.	2010.	2001.	2214.	0.	204.	6.	9.
1	84	6	1	1	8	17	2022.	2023.	1957.	2169.	0.	146.	1.	66.
1	84	10	0	1	12	5	2026.	2026.	2002.	2192.	0.	166.	0.	24.
1	84	10	0	1	13	6	2026.	2026.	2022.	2239.	0.	213.	0.	4.
2	85	11	0	2	2	2	2051.	2311.	2311.	2677.	260.	366.	260.	0.
1	85	18	14	1	4	7	2058.	2072.	2030.	2241.	0.	169.	14.	42.
1	85	20	12	1	5	8	2060.	2072.	2054.	2242.	0.	170.	12.	18.
1	86	5	4	1	6	9	2069.	2073.	2046.	2241.	0.	168.	4.	27.
1	88	12	0	1	9	0	2124.	2124.	2026.	2248.	0.	124.	0.	98.
1	90	6	0	1	10	0	2166.	2166.	2027.	2287.	0.	121.	0.	139.
1	90	8	5	1	8	1	2168.	2173.	2169.	2263.	0.	90.	5.	4.
1	90	10	3	1	11	2	2170.	2173.	2119.	2366.	0.	193.	3.	54.
1	90	11	2	1	14	3	2171.	2173.	2046.	2246.	0.	73.	2.	127.
1	91	23	7	1	12	1	2207.	2214.	2192.	2366.	0.	152.	7.	22.
1	92	9	6	1	7	1	2217.	2223.	2214.	2391.	0.	168.	6.	9.
1	92	19	11	1	15	1	2227.	2238.	2070.	2296.	0.	58.	11.	168.
1	93	1	5	1	13	2	2233.	2239.	2239.	2359.	1.	120.	6.	0.
1	93	4	2	1	4	3	2236.	2241.	2241.	2334.	3.	94.	5.	0.
1	95	17	13	1	5	1	2297.	2310.	2242.	2479.	0.	169.	13.	68.
1	95	21	9	1	6	2	2301.	2310.	2241.	2455.	0.	145.	9.	69.
1	96	17	14	1	3	1	2321.	2335.	2313.	2479.	0.	144.	14.	22.
3	96	17	14	3	1	1	2321.	2335.	1207.	2551.	0.	216.	14.	1128.
4	96	21	10	4	1	1	2325.	2335.	2295.	2456.	0.	121.	10.	40.
3	97	3	5	3	1	2	2331.	2551.	2551.	2747.	215.	196.	220.	0.
1	97	9	0	1	4	0	2337.	2337.	2334.	2553.	0.	216.	0.	3.
1	97	10	0	1	8	0	2338.	2338.	2263.	2531.	0.	193.	0.	75.
1	97	22	10	1	9	1	2350.	2360.	2248.	2577.	0.	217.	10.	112.
1	98	3	6	1	10	2	2355.	2361.	2287.	2554.	0.	193.	6.	74.
1	98	11	0	1	13	0	2363.	2363.	2359.	2530.	0.	167.	0.	4.
1	98	12	0	1	14	0	2364.	2364.	2246.	2582.	0.	218.	0.	118.
1	98	18	15	1	11	1	2370.	2385.	2366.	2578.	0.	193.	15.	19.
1	98	18	15	1	12	2	2370.	2385.	2366.	2506.	0.	121.	15.	19.
1	98	22	11	1	15	3	2374.	2385.	2296.	2601.	0.	216.	11.	89.
1	99	11	0	1	7	1	2387.	2391.	2391.	2530.	4.	139.	4.	0.
1	99	13	0	1	6	2	2389.	2455.	2455.	2626.	66.	171.	66.	0.
1	99	23	11	1	5	2	2399.	2479.	2479.	2579.	69.	100.	80.	0.
1	100	5	6	1	3	3	2405.	2479.	2479.	2675.	68.	196.	74.	0.
1	100	19	16	1	1	4	2419.	2505.	2505.	2651.	70.	146.	86.	0.
1	101	4	8	1	12	5	2428.	2506.	2506.	2652.	70.	147.	78.	0.
2	101	17	0	1	2	6	2441.	2527.	2527.	3108.	86.	582.	86.	0.
1	101	21	15	1	13	7	2445.	2530.	2530.	2749.	70.	219.	85.	0.
2	101	22	14	2	1	1	2446.	2578.	2578.	3061.	118.	483.	132.	0.
2	102	7	6	1	1	7	2455.	2651.	2651.	2946.	190.	294.	196.	0.
4	102	12	1	4	1	1	2460.	2461.	2456.	2574.	0.	113.	1.	5.
1	102	14	0	1	7	8	2462.	2530.	2530.	2702.	68.	172.	68.	0.
1	102	17	0	1	8	9	2465.	2531.	2531.	2719.	66.	188.	66.	0.
1	103	10	4	1	4	8	2482.	2553.	2553.	2647.	67.	94.	71.	0.
1	105	9	0	1	10	6	2529.	2554.	2554.	2695.	25.	141.	25.	0.
1	105	14	2	1	9	6	2534.	2577.	2577.	2742.	41.	165.	43.	0.
4	105	17	0	4	1	1	2537.	2574.	2574.	2767.	37.	192.	37.	0.
1	106	5	1	1	11	7	2549.	2578.	2578.	2753.	28.	176.	29.	0.
2	106	8	0	1	3	8	2552.	2675.	2675.	3079.	123.	404.	123.	0.
1	107	2	4	1	5	9	2570.	2579.	2579.	2767.	5.	188.	9.	0.
2	107	2	4	2	2	2	2570.	2677.	2677.	2938.	103.	261.	107.	0.
1	107	8	0	1	14	10	2576.	2582.	2582.	2695.	6.	113.	6.	0.
1	107	8	0	1	15	11	2576.	2601.	2601.	2706.	25.	105.	25.	0.
1	107	23	7	1	6	12	2591.	2626.	2626.	2803.	28.	177.	35.	0.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	108	7	0	2	2	2	2599.	2938.	2938.	3403.	339.	465.	339.	0.
1	108	21	10	1	4	13	2613.	2647.	2647.	2827.	24.	180.	34.	0.
1	109	12	0	1	12	14	2628.	2652.	2652.	2817.	24.	164.	24.	0.
2	109	17	3	1	1	15	2633.	2946.	2946.	3477.	310.	531.	313.	0.
1	110	20	13	1	10	9	2660.	2695.	2695.	2866.	22.	171.	35.	0.
4	111	5	5	4	1	1	2669.	2767.	2767.	2914.	93.	148.	98.	0.
1	111	21	13	1	14	3	2685.	2698.	2695.	2842.	0.	144.	13.	3.
1	112	4	7	1	7	4	2692.	2702.	2702.	2867.	3.	165.	10.	0.
1	112	17	6	1	15	5	2705.	2711.	2706.	2868.	0.	157.	6.	5.
1	112	23	12	1	8	6	2711.	2723.	2719.	2868.	0.	145.	12.	4.
2	113	9	3	2	1	2	2721.	3061.	3061.	3684.	337.	624.	340.	0.
1	113	10	2	1	9	7	2722.	2742.	2742.	2892.	18.	150.	20.	0.
1	114	3	3	1	13	8	2739.	2749.	2749.	2886.	7.	137.	10.	0.
1	114	8	5	1	11	9	2744.	2753.	2753.	2910.	4.	157.	9.	0.
4	114	17	0	4	1	2	2753.	2914.	2914.	3041.	161.	126.	161.	0.
4	115	1	5	4	1	3	2761.	3041.	3041.	3247.	275.	206.	280.	0.
1	115	13	1	1	5	10	2773.	2774.	2767.	2982.	0.	208.	1.	7.
1	116	8	0	1	6	11	2792.	2803.	2803.	2959.	11.	156.	11.	0.
1	116	9	6	1	12	12	2793.	2817.	2817.	2982.	18.	166.	24.	0.
1	116	10	5	1	4	13	2794.	2827.	2827.	3078.	28.	251.	33.	0.
1	116	23	7	1	14	14	2807.	2842.	2842.	2967.	28.	125.	35.	0.
4	117	0	6	4	1	3	2808.	3247.	3247.	3391.	433.	144.	439.	0.
1	118	8	0	1	10	15	2840.	2866.	2866.	3041.	26.	175.	26.	0.
1	118	22	8	1	7	16	2854.	2867.	2867.	3065.	5.	198.	13.	0.
2	119	1	5	1	3	17	2857.	3079.	3079.	3511.	217.	432.	222.	0.
1	119	20	10	1	8	18	2876.	2886.	2868.	3006.	0.	120.	10.	18.
4	120	1	6	4	1	4	2881.	3391.	3391.	3559.	504.	169.	510.	0.
1	120	22	9	1	9	19	2902.	2911.	2892.	3103.	0.	192.	9.	19.
2	121	4	4	1	2	20	2908.	3108.	3108.	3710.	196.	601.	200.	0.
1	122	4	5	1	11	21	2932.	2937.	2910.	3108.	0.	171.	5.	27.
1	122	9	0	1	13	22	2937.	2937.	2886.	3105.	0.	168.	0.	51.
1	122	11	0	1	15	23	2939.	2939.	2868.	3082.	0.	143.	0.	71.
4	122	20	13	4	1	4	2948.	3559.	3559.	3730.	598.	170.	611.	0.
3	122	22	11	3	1	1	2950.	2961.	2747.	3177.	0.	216.	11.	214.
1	123	0	10	1	6	8	2952.	2962.	2959.	3107.	0.	145.	10.	3.
1	123	6	4	1	14	9	2958.	2967.	2967.	3131.	5.	164.	9.	0.
1	123	22	12	1	5	10	2974.	2986.	2982.	3178.	0.	192.	12.	4.
2	124	6	5	2	2	2	2982.	3403.	3403.	3950.	416.	547.	421.	0.
1	125	4	8	1	8	11	3004.	3012.	3006.	3252.	0.	240.	8.	6.
1	125	5	7	1	12	12	3005.	3012.	2982.	3109.	0.	97.	7.	30.
1	125	11	1	1	10	13	3011.	3041.	3041.	3229.	29.	188.	30.	0.
1	126	7	6	1	7	14	3031.	3065.	3065.	3198.	28.	133.	34.	0.
2	128	15	0	1	1	12	3087.	3477.	3477.	4038.	390.	562.	390.	0.
1	129	21	9	1	4	2	3117.	3126.	3078.	3305.	0.	179.	9.	48.
1	130	15	2	1	6	3	3135.	3137.	3107.	3250.	0.	113.	2.	30.
1	131	4	2	1	9	4	3148.	3150.	3103.	3298.	0.	148.	2.	47.
1	131	11	0	1	11	5	3155.	3155.	3108.	3275.	0.	120.	0.	47.
1	132	2	5	1	12	6	3170.	3175.	3109.	3331.	0.	156.	5.	66.
1	132	2	5	1	13	7	3170.	3175.	3105.	3296.	0.	121.	5.	70.
4	132	10	0	4	1	4	3178.	3730.	3730.	3871.	552.	141.	552.	0.
1	132	18	13	1	5	8	3186.	3199.	3178.	3403.	0.	204.	13.	21.
1	133	3	5	1	7	9	3195.	3200.	3198.	3324.	0.	124.	5.	2.
1	133	23	9	1	14	10	3215.	3224.	3131.	3417.	0.	193.	9.	93.
1	134	2	7	1	15	11	3218.	3225.	3082.	3417.	0.	192.	7.	143.
1	134	4	5	1	10	12	3220.	3229.	3229.	3445.	4.	216.	9.	0.
2	135	10	0	1	3	13	3250.	3511.	3511.	3736.	261.	225.	261.	0.
1	135	12	0	1	6	14	3252.	3252.	3250.	3430.	0.	178.	0.	2.
1	135	15	0	1	8	15	3255.	3255.	3252.	3371.	0.	116.	0.	3.
1	137	3	9	1	9	16	3291.	3300.	3298.	3520.	0.	220.	9.	2.
1	137	19	17	1	4	17	3307.	3324.	3305.	3492.	0.	168.	17.	19.
1	138	11	2	1	7	18	3323.	3325.	3324.	3511.	0.	186.	2.	1.
1	138	14	0	1	11	19	3326.	3326.	3275.	3486.	0.	160.	0.	51.
1	138	16	0	1	13	20	3328.	3328.	3296.	3518.	0.	190.	0.	32.
1	138	19	11	1	12	21	3331.	3342.	3331.	3439.	0.	97.	11.	11.
1	139	5	1	1	8	22	3341.	3371.	3371.	3518.	29.	147.	30.	0.
1	140	3	3	1	5	23	3363.	3403.	3403.	3558.	37.	155.	40.	0.

1	140	17	0	1	14	24	3377.	3417.	3417.	3591.	40.	174.	40.	0.
1	142	5	1	1	15	25	3413.	3417.	3417.	3522.	3.	105.	4.	0.
1	142	14	3	1	6	26	3422.	3430.	3430.	3569.	5.	139.	8.	0.
1	142	14	3	1	12	27	3422.	3439.	3439.	3666.	14.	227.	17.	0.
1	143	9	0	1	10	28	3441.	3445.	3445.	3606.	4.	161.	4.	0.
1	145	0	8	1	11	17	3480.	3488.	3486.	3731.	0.	243.	8.	2.
1	145	12	0	1	4	18	3492.	3492.	3492.	3683.	0.	191.	0.	0.
1	146	21	12	1	7	1	3525.	3537.	3511.	3684.	0.	147.	12.	26.
1	148	0	11	1	5	1	3552.	3563.	3558.	3664.	0.	101.	11.	5.
1	148	18	17	1	6	1	3570.	3587.	3569.	3708.	0.	121.	17.	18.
1	148	18	17	1	8	2	3570.	3587.	3518.	3732.	0.	145.	17.	69.
1	150	15	0	1	9	0	3615.	3615.	3520.	3798.	0.	183.	0.	95.
1	151	0	6	1	10	1	3624.	3630.	3606.	3798.	0.	168.	6.	24.
1	152	7	0	1	13	0	3655.	3655.	3518.	3871.	0.	216.	0.	137.
1	152	15	0	1	14	0	3663.	3663.	3591.	3823.	0.	160.	0.	72.
1	153	2	4	1	5	1	3674.	3678.	3664.	3847.	0.	169.	4.	14.
1	153	17	0	1	4	0	3689.	3689.	3683.	3871.	0.	182.	0.	6.
1	153	22	8	1	7	1	3694.	3702.	3684.	3846.	0.	144.	8.	18.
1	154	19	11	1	2	1	3715.	3726.	3710.	3870.	0.	144.	11.	16.
1	154	22	8	1	6	2	3718.	3726.	3708.	3929.	0.	203.	8.	18.
1	156	1	6	1	3	1	3745.	3751.	3736.	3896.	0.	145.	6.	15.
4	157	1	7	4	1	1	3769.	3871.	3871.	4042.	95.	171.	102.	0.
1	158	0	9	1	8	1	3792.	3801.	3732.	3970.	0.	169.	9.	69.
1	159	5	5	1	9	1	3821.	3826.	3798.	3971.	0.	145.	5.	28.
1	159	13	0	1	10	0	3829.	3829.	3798.	4018.	0.	189.	0.	31.
2	159	17	5	2	1	1	3833.	3838.	3684.	4043.	0.	205.	5.	154.
1	159	21	13	1	5	1	3837.	3850.	3847.	3994.	0.	144.	13.	3.
1	160	21	14	1	2	1	3861.	3875.	3870.	4044.	0.	169.	14.	5.
1	161	18	18	1	3	1	3882.	3900.	3896.	4092.	0.	192.	18.	4.
1	162	1	5	1	4	2	3889.	3894.	3871.	4069.	0.	175.	5.	23.
2	162	11	2	2	2	1	3899.	3950.	3950.	4481.	49.	531.	51.	0.
1	163	8	6	1	7	1	3920.	3926.	3846.	4062.	0.	136.	6.	80.
1	163	8	6	1	11	2	3920.	3926.	3731.	4070.	0.	144.	6.	195.
1	164	11	4	1	6	1	3947.	3951.	3929.	4087.	0.	136.	4.	22.
1	164	16	0	1	12	0	3952.	3952.	3666.	4182.	0.	230.	0.	286.
1	164	20	10	1	13	1	3956.	3966.	3871.	4159.	0.	193.	10.	95.
1	166	1	5	1	8	1	3985.	3990.	3970.	4158.	0.	168.	5.	20.
1	166	3	3	1	9	2	3987.	3990.	3971.	4162.	0.	172.	3.	19.
1	166	4	2	1	14	3	3988.	3990.	3823.	4242.	0.	252.	2.	167.
1	167	6	0	1	5	0	4014.	4014.	3994.	4188.	0.	174.	0.	20.
1	167	19	11	1	10	1	4027.	4038.	4018.	4182.	0.	144.	11.	20.
1	168	1	6	1	1	2	4033.	4039.	4038.	4208.	0.	169.	6.	1.
1	169	0	8	1	2	1	4056.	4064.	4044.	4304.	0.	240.	8.	20.
1	169	9	0	1	7	0	4065.	4065.	4062.	4257.	0.	192.	0.	3.
1	169	10	0	1	15	0	4066.	4066.	3522.	4166.	0.	100.	0.	544.
1	169	12	0	1	4	1	4068.	4069.	4069.	4184.	1.	115.	1.	0.
1	169	13	0	1	11	2	4069.	4070.	4070.	4208.	1.	138.	1.	0.
1	169	18	14	1	6	1	4074.	4088.	4087.	4280.	0.	192.	14.	1.
4	170	1	8	4	1	1	4081.	4089.	4042.	4259.	0.	170.	8.	47.
1	170	8	1	1	3	1	4088.	4092.	4092.	4308.	3.	215.	4.	0.
1	170	11	0	1	8	2	4091.	4158.	4158.	4283.	67.	124.	67.	0.
1	170	20	13	1	13	2	4100.	4159.	4159.	4282.	46.	123.	59.	0.
1	171	13	0	1	9	3	4117.	4162.	4162.	4354.	45.	192.	45.	0.
1	171	17	17	1	15	4	4121.	4166.	4166.	4379.	28.	213.	45.	0.
1	172	1	10	1	12	5	4129.	4182.	4182.	4333.	43.	151.	53.	0.
2	172	17	18	2	1	1	4145.	4163.	4043.	4620.	0.	457.	18.	120.
4	173	22	14	4	1	1	4174.	4259.	4259.	4453.	71.	194.	85.	0.
1	174	22	8	1	4	1	4198.	4206.	4184.	4357.	0.	151.	8.	22.
1	175	6	0	1	5	0	4206.	4206.	4188.	4374.	0.	168.	0.	18.
1	175	11	3	1	1	1	4211.	4214.	4208.	4375.	0.	161.	3.	6.
1	175	19	11	1	10	1	4219.	4230.	4182.	4327.	0.	97.	11.	48.
1	175	21	9	1	11	2	4221.	4230.	4208.	4375.	0.	145.	9.	22.
2	176	11	4	1	2	1	4235.	4304.	4304.	4743.	65.	439.	69.	0.
1	176	19	11	1	14	2	4243.	4254.	4242.	4359.	0.	105.	11.	12.
1	176	23	7	1	7	3	4247.	4257.	4257.	4446.	3.	189.	10.	0.
2	177	3	3	1	3	4	4251.	4308.	4308.	4793.	54.	485.	57.	0.

2	178	4	2	1	1	5	4276.	4375.	4375.	4831.	97.	456.	99.	0.
1	179	8	0	1	6	6	4304.	4304.	4280.	4435.	0.	131.	0.	24.
1	179	9	0	1	8	4	4305.	4305.	4283.	4434.	0.	129.	0.	22.
2	180	0	7	2	2	1	4320.	4481.	4481.	4786.	154.	305.	161.	0.
1	181	3	5	1	10	4	4347.	4352.	4327.	4592.	0.	240.	5.	25.
1	181	4	4	1	12	5	4348.	4352.	4333.	4496.	0.	144.	4.	19.
1	181	6	2	1	13	6	4350.	4352.	4282.	4524.	0.	172.	2.	70.
1	182	6	3	1	4	7	4374.	4377.	4357.	4524.	0.	147.	3.	20.
1	184	6	5	1	5	1	4422.	4427.	4374.	4668.	0.	241.	5.	53.
1	184	18	17	1	6	1	4434.	4451.	4435.	4644.	0.	193.	17.	16.
1	184	21	14	1	7	2	4437.	4451.	4446.	4572.	0.	121.	14.	5.
1	184	23	12	1	8	3	4439.	4451.	4434.	4596.	0.	145.	12.	17.
2	185	17	0	2	1	2	4457.	4620.	4620.	5028.	163.	408.	163.	0.
1	185	18	18	1	9	1	4458.	4476.	4354.	4645.	0.	167.	18.	122.
1	185	21	15	1	11	2	4461.	4476.	4375.	4596.	0.	120.	15.	101.
1	186	3	3	1	14	3	4467.	4470.	4359.	4669.	0.	199.	3.	111.
1	186	5	1	1	15	4	4469.	4470.	4379.	4598.	0.	128.	1.	91.
1	186	7	6	1	12	5	4471.	4496.	4496.	4626.	19.	129.	25.	0.
1	188	22	8	1	4	1	4534.	4542.	4524.	4616.	0.	74.	8.	18.
1	189	6	0	1	13	0	4542.	4542.	4524.	4686.	0.	144.	0.	18.
1	189	23	7	1	7	1	4559.	4572.	4572.	4806.	6.	234.	13.	0.
1	190	3	3	1	10	2	4563.	4592.	4592.	4783.	26.	190.	29.	0.
1	190	9	0	1	8	3	4569.	4596.	4596.	4770.	27.	174.	27.	0.
1	190	11	6	1	11	4	4571.	4596.	4596.	4783.	19.	186.	25.	0.
1	190	23	7	1	15	4	4583.	4598.	4598.	4737.	8.	139.	15.	0.
1	191	3	3	1	4	5	4587.	4616.	4616.	4831.	26.	215.	29.	0.
1	191	8	0	1	12	6	4592.	4626.	4626.	4831.	34.	205.	34.	0.
1	192	17	14	1	6	2	4625.	4644.	4644.	4783.	5.	139.	19.	0.
1	193	3	5	1	9	2	4635.	4645.	4645.	4883.	5.	239.	10.	0.
2	193	3	5	1	2	3	4635.	4743.	4743.	5144.	103.	401.	108.	0.
2	193	9	0	2	2	1	4641.	4786.	4786.	5288.	145.	502.	145.	0.
1	194	5	4	1	5	2	4661.	4668.	4668.	4787.	3.	119.	7.	0.
4	194	13	0	4	1	0	4669.	4669.	4453.	4786.	0.	117.	0.	216.
1	194	17	16	1	13	3	4673.	4689.	4686.	4833.	0.	144.	16.	3.
3	195	0	10	3	1	1	4680.	4690.	3177.	4979.	0.	289.	10.	1513.
3	196	7	4	3	1	1	4711.	4979.	4979.	5196.	264.	217.	268.	0.
4	196	19	16	4	1	1	4723.	4786.	4786.	4956.	47.	170.	63.	0.
1	197	0	12	1	14	4	4728.	4740.	4669.	4957.	0.	217.	12.	71.
1	197	7	5	1	15	5	4735.	4740.	4737.	4909.	0.	169.	5.	3.
1	197	15	0	1	8	6	4743.	4770.	4770.	4984.	27.	214.	27.	0.
1	197	21	15	1	11	2	4749.	4783.	4783.	4959.	19.	177.	34.	0.
2	198	5	1	1	3	3	4757.	4793.	4793.	5078.	35.	285.	36.	0.
1	198	6	0	1	10	4	4758.	4783.	4783.	4909.	25.	127.	25.	0.
2	198	21	9	1	1	4	4773.	4831.	4831.	5334.	49.	503.	58.	0.
1	199	2	4	1	6	5	4778.	4783.	4783.	4983.	1.	200.	5.	0.
1	199	8	6	1	5	5	4784.	4790.	4787.	4910.	0.	120.	6.	3.
1	199	20	10	1	7	4	4796.	4806.	4806.	5033.	0.	227.	10.	0.
1	200	7	0	1	4	5	4807.	4831.	4831.	5046.	24.	216.	24.	0.
4	200	14	1	4	1	1	4814.	4956.	4956.	5128.	141.	172.	142.	0.
1	200	21	9	1	12	6	4821.	4831.	4831.	4951.	1.	120.	10.	0.
1	201	5	1	1	13	7	4829.	4833.	4833.	4926.	3.	93.	4.	0.
2	202	2	4	2	1	1	4850.	5028.	5028.	5681.	174.	653.	178.	0.
1	202	3	3	1	9	1	4851.	4883.	4883.	5119.	29.	235.	32.	0.
2	202	4	2	1	3	2	4852.	5078.	5078.	5529.	224.	451.	226.	0.
1	203	6	0	1	15	3	4878.	4909.	4909.	5051.	31.	142.	31.	0.
2	205	3	5	1	2	3	4923.	5144.	5144.	5744.	216.	600.	221.	0.
1	205	4	4	1	5	4	4924.	4928.	4910.	5073.	0.	145.	4.	18.
2	205	13	0	2	2	2	4933.	5288.	5288.	5796.	355.	508.	355.	0.
2	205	18	14	1	1	5	4938.	5334.	5334.	5768.	382.	434.	396.	0.
1	206	20	13	1	10	6	4964.	4977.	4909.	5077.	0.	100.	13.	68.
1	207	12	0	1	11	7	4980.	4980.	4959.	5077.	0.	97.	0.	21.
1	208	0	11	1	6	8	4992.	5003.	4983.	5123.	0.	120.	11.	20.
4	208	6	5	4	1	1	4998.	5128.	5128.	5267.	125.	140.	130.	0.
1	208	7	4	1	8	9	4999.	5003.	4984.	5104.	0.	101.	4.	19.
1	208	7	4	1	12	10	4999.	5003.	4951.	5184.	0.	181.	4.	52.
1	208	9	2	1	13	11	5001.	5003.	4926.	5171.	0.	168.	2.	77

1	209	8	4	1	14	12	5024.	5028.	4957.	5125.	0.	97.	4.	71.
1	209	18	18	1	4	13	5034.	5052.	5046.	5247.	0.	195.	18.	6.
1	209	22	14	1	7	14	5038.	5052.	5033.	5196.	0.	144.	14.	19.
1	210	5	1	1	15	15	5045.	5051.	5051.	5191.	5.	140.	6.	0.
1	211	1	5	1	5	16	5065.	5073.	5073.	5198.	3.	125.	8.	0.
1	211	10	4	1	10	17	5074.	5078.	5077.	5263.	0.	185.	4.	1.
2	211	20	10	1	3	16	5084.	5529.	5529.	6151.	435.	622.	445.	0.
1	211	21	9	1	11	17	5085.	5094.	5077.	5286.	0.	192.	9.	17.
1	211	23	7	1	8	18	5087.	5104.	5104.	5144.	10.	40.	17.	0.
2	212	15	0	2	1	2	5103.	5681.	5681.	6222.	578.	541.	578.	0.
1	215	12	18	1	6	17	5172.	5190.	5123.	5335.	0.	145.	18.	67.
2	216	23	8	1	2	18	5207.	5744.	5744.	6200.	529.	456.	537.	0.
1	217	14	18	1	5	19	5222.	5240.	5198.	5360.	0.	120.	18.	42.
1	218	16	17	1	4	20	5248.	5265.	5247.	5386.	0.	121.	17.	18.
1	219	7	3	1	7	21	5263.	5266.	5196.	5434.	0.	168.	3.	70.
1	220	13	0	1	8	22	5293.	5293.	5144.	5435.	0.	142.	0.	149.
1	221	11	1	1	9	23	5315.	5316.	5119.	5436.	0.	120.	1.	197.
1	221	19	17	1	6	24	5323.	5340.	5335.	5485.	0.	145.	17.	5.
1	222	16	0	1	10	12	5344.	5344.	5263.	5502.	0.	158.	0.	81.
2	223	1	5	1	1	13	5353.	5768.	5768.	6175.	410.	406.	415.	0.
1	223	19	11	1	5	14	5371.	5382.	5360.	5534.	0.	152.	11.	22.
1	224	7	0	1	11	15	5383.	5383.	5286.	5502.	0.	119.	0.	97.
1	224	15	0	1	4	16	5391.	5391.	5386.	5502.	0.	111.	0.	5.
1	225	2	4	1	12	17	5402.	5406.	5184.	5550.	0.	144.	4.	222.
1	225	15	1	1	13	18	5415.	5416.	5171.	5529.	0.	113.	1.	245.
1	225	18	12	1	14	19	5418.	5430.	5125.	5584.	0.	154.	12.	305.
4	226	8	0	4	1	0	5432.	5432.	5267.	5562.	0.	130.	0.	165.
1	226	15	2	1	7	20	5439.	5441.	5434.	5598.	0.	157.	2.	7.
1	226	22	8	1	8	21	5446.	5454.	5435.	5623.	0.	169.	8.	19.
1	227	10	0	1	9	22	5458.	5458.	5436.	5658.	0.	200.	0.	22.
1	229	18	14	1	4	23	5514.	5528.	5502.	5672.	0.	144.	14.	26.
2	229	22	10	2	2	2	5518.	5796.	5796.	6276.	268.	480.	278.	0.
1	230	2	7	1	6	24	5522.	5529.	5485.	5650.	0.	121.	7.	44.
1	230	18	15	1	5	21	5538.	5553.	5534.	5697.	0.	144.	15.	19.
2	230	18	15	1	3	22	5538.	6151.	6151.	6681.	598.	531.	613.	0.
2	230	20	13	1	1	23	5540.	6175.	6175.	6586.	622.	411.	635.	0.
1	231	6	4	1	10	24	5550.	5554.	5502.	5750.	0.	196.	4.	52.
1	232	5	6	1	11	25	5573.	5579.	5502.	5748.	0.	169.	6.	77.
1	233	10	2	1	7	26	5602.	5604.	5598.	5773.	0.	169.	2.	6.
1	233	11	1	1	12	27	5603.	5604.	5550.	5821.	0.	217.	1.	54.
1	233	13	0	1	13	28	5605.	5605.	5529.	5820.	0.	215.	0.	76.
1	234	18	12	1	8	29	5634.	5646.	5623.	5695.	0.	49.	12.	23.
1	237	10	6	1	4	30	5698.	5704.	5672.	5945.	0.	241.	6.	32.
1	237	21	9	1	5	31	5709.	5718.	5697.	5886.	0.	168.	9.	21.
1	239	3	3	1	6	32	5739.	5742.	5650.	5982.	0.	240.	3.	92.
1	239	16	14	1	8	25	5752.	5766.	5695.	5910.	0.	144.	14.	71.
1	239	17	13	1	9	26	5753.	5766.	5658.	5934.	0.	168.	13.	108.
1	240	4	3	1	10	27	5764.	5767.	5750.	5887.	0.	120.	3.	17.
1	240	5	2	1	11	28	5765.	5767.	5748.	5888.	0.	121.	2.	19.
2	240	16	15	1	2	16	5776.	6200.	6200.	6633.	409.	434.	424.	0.
1	241	13	0	1	7	17	5797.	5797.	5773.	5961.	0.	164.	0.	24.
1	242	4	5	1	14	18	5812.	5817.	5584.	5937.	0.	120.	5.	233.
1	242	5	4	1	15	19	5813.	5817.	5191.	5941.	0.	124.	4.	626.
1	242	18	15	1	12	20	5826.	5841.	5821.	6057.	0.	216.	15.	20.
1	244	2	9	1	13	21	5858.	5867.	5820.	6039.	0.	172.	9.	47.
1	244	19	16	1	5	22	5875.	5891.	5886.	6036.	0.	145.	16.	5.
4	244	21	14	4	1	1	5877.	5891.	5562.	6036.	0.	145.	14.	329.
1	246	11	2	1	8	23	5915.	5917.	5910.	6079.	0.	162.	2.	7.
1	247	1	5	1	10	24	5929.	5934.	5887.	6040.	0.	106.	5.	47.
1	247	13	1	1	9	25	5941.	5942.	5934.	6150.	0.	208.	1.	8.
1	247	14	0	1	11	26	5942.	5942.	5888.	6088.	0.	146.	0.	54.
1	247	15	0	1	14	27	5943.	5943.	5937.	6110.	0.	167.	0.	6.
1	247	19	11	1	4	28	5947.	5958.	5945.	6039.	0.	81.	11.	13.
1	248	11	4	1	7	29	5963.	5967.	5961.	6150.	0.	183.	4.	6.
1	248	14	1	1	15	30	5966.	5967.	5941.	6127.	0.	160.	1.	26.
2	248	17	0	2	1	1	5969.	6222.	6222.	6631.	253.	408.	253.	0.

1	249	0	6	1	6	31	5976.	5982.	5982.	6209.	0.	227.	6.	0.
1	249	5	1	1	5	32	5981.	6036.	6036.	6199.	54.	162.	55.	0.
1	249	10	6	1	4	33	5986.	6039.	6039.	6223.	47.	183.	53.	0.
1	249	12	4	1	13	34	5988.	6039.	6039.	6200.	47.	161.	51.	0.
2	249	14	2	2	2	2	5990.	6276.	6276.	6750.	284.	475.	286.	0.
4	249	14	2	4	1	1	5990.	6036.	6036.	6199.	44.	163.	46.	0.
1	250	13	4	1	10	35	6013.	6040.	6040.	6198.	23.	158.	27.	0.
1	251	16	2	1	12	36	6040.	6057.	6057.	6249.	15.	192.	17.	0.
4	252	7	0	4	1	1	6055.	6199.	6199.	6368.	144.	169.	144.	0.
2	252	11	0	1	1	37	6059.	6586.	6586.	6943.	527.	357.	527.	0.
3	252	18	13	3	1	1	6066.	6079.	5196.	6348.	0.	269.	13.	883.
2	253	2	6	2	1	3	6074.	6631.	6631.	6992.	551.	361.	557.	0.
1	253	13	0	1	8	38	6085.	6085.	6079.	6296.	0.	211.	0.	6.
1	254	2	7	1	11	39	6098.	6105.	6088.	6298.	0.	193.	7.	17.
2	254	2	7	1	2	40	6098.	6633.	6633.	7042.	528.	408.	535.	0.
1	256	10	1	1	7	40	6154.	6155.	6150.	6299.	0.	144.	1.	5.
1	256	22	13	1	9	41	6166.	6179.	6150.	6348.	0.	169.	13.	29.
1	257	4	8	1	14	42	6172.	6180.	6110.	6353.	0.	173.	8.	70.
1	257	8	4	1	15	29	6176.	6180.	6127.	6325.	0.	145.	4.	53.
1	257	16	0	1	10	30	6184.	6198.	6198.	6348.	14.	150.	14.	0.
1	258	17	0	1	5	10	6209.	6209.	6199.	6438.	0.	229.	0.	10.
1	259	2	4	1	6	11	6218.	6222.	6209.	6398.	0.	176.	4.	13.
1	260	5	1	1	4	12	6245.	6246.	6223.	6343.	0.	97.	1.	23.
2	262	6	0	1	3	13	6294.	6681.	6681.	7351.	387.	669.	387.	0.
1	263	2	4	1	7	14	6314.	6318.	6299.	6486.	0.	168.	4.	19.
1	263	17	13	1	8	15	6329.	6342.	6296.	6535.	0.	193.	13.	46.
2	263	17	13	2	2	2	6329.	6750.	6750.	7086.	408.	336.	421.	0.
1	264	7	0	1	4	16	6343.	6343.	6343.	6511.	0.	168.	0.	0.
1	264	21	10	1	9	17	6357.	6367.	6348.	6536.	0.	169.	10.	19.
1	265	8	0	1	10	18	6368.	6368.	6348.	6561.	0.	193.	0.	20.
1	265	11	0	1	11	19	6371.	6371.	6298.	6560.	0.	189.	0.	73.
1	265	18	14	1	12	20	6378.	6392.	6249.	6560.	0.	168.	14.	143.
1	265	20	12	1	13	21	6380.	6392.	6200.	6561.	0.	169.	12.	192.
1	266	7	2	1	14	22	6391.	6393.	6353.	6538.	0.	145.	2.	40.
1	268	5	6	1	5	23	6437.	6443.	6438.	6588.	0.	145.	6.	5.
1	268	10	1	1	6	24	6442.	6443.	6398.	6616.	0.	173.	1.	45.
1	268	10	1	1	15	25	6442.	6443.	6325.	6588.	0.	145.	1.	118.
1	269	19	17	1	7	26	6475.	6492.	6486.	6708.	0.	216.	17.	6.
1	272	0	6	1	4	27	6528.	6534.	6511.	6736.	0.	202.	6.	23.
1	272	9	6	1	8	28	6537.	6543.	6535.	6679.	0.	136.	6.	8.
1	272	15	0	1	9	29	6543.	6543.	6536.	6702.	0.	159.	0.	7.
1	273	19	11	1	10	30	6571.	6582.	6561.	6703.	0.	121.	11.	21.
1	274	4	2	1	11	31	6580.	6582.	6560.	6726.	0.	144.	2.	22.
3	274	17	0	3	1	0	6593.	6593.	6348.	6834.	0.	241.	0.	245.
1	275	15	3	1	5	29	6615.	6618.	6588.	6787.	0.	169.	3.	30.
1	275	16	2	1	6	30	6616.	6618.	6616.	6774.	0.	156.	2.	2.
1	276	10	0	1	12	22	6634.	6634.	6560.	6799.	0.	165.	0.	74.
1	276	12	0	1	13	23	6636.	6636.	6561.	6752.	0.	116.	0.	75.
1	276	13	6	1	14	24	6637.	6643.	6538.	6829.	0.	186.	6.	105.
1	276	18	13	1	15	25	6642.	6655.	6588.	6799.	0.	144.	13.	67.
2	277	3	5	1	1	26	6651.	6943.	6943.	7233.	287.	290.	292.	0.
1	277	7	1	1	8	27	6655.	6679.	6679.	6849.	23.	170.	24.	0.
1	277	8	0	1	9	28	6656.	6702.	6702.	6921.	46.	218.	46.	0.
2	278	17	4	2	1	2	6689.	6992.	6992.	7402.	299.	410.	303.	0.
1	279	0	10	1	10	4	6696.	6706.	6703.	6899.	0.	193.	10.	3.
1	280	20	15	1	4	5	6740.	6755.	6736.	6900.	0.	145.	15.	19.
2	281	18	18	1	2	6	6762.	7042.	7042.	7428.	262.	386.	280.	0.
1	281	19	17	1	6	7	6763.	6780.	6774.	6900.	0.	120.	17.	6.
1	283	20	10	1	5	8	6812.	6822.	6787.	6903.	0.	81.	10.	35.
1	284	3	3	1	7	9	6819.	6822.	6708.	6991.	0.	169.	3.	114.
1	284	6	0	1	11	10	6822.	6822.	6726.	6952.	0.	130.	0.	96.
1	285	7	0	1	12	11	6847.	6847.	6799.	7014.	0.	167.	0.	48.
1	285	12	4	1	8	12	6852.	6856.	6849.	7087.	0.	231.	4.	7.
2	285	22	8	2	2	2	6862.	7086.	7086.	7505.	216.	419.	224.	0.
1	286	2	4	1	13	13	6866.	6870.	6752.	7063.	0.	193.	4.	118.
4	287	1	5	4	1	1	6889.	6894.	6348.	7113.	0.	219.	5.	576.

2	287	20	10	1	1	14	6908.	7233.	7233.	7663.	315.	430.	325.	0.
1	287	21	9	1	4	15	6909.	6918.	6900.	7015.	0.	97.	9.	18.
1	287	22	8	1	5	16	6910.	6918.	6903.	7134.	0.	216.	8.	15.
1	289	1	7	1	6	17	6937.	6944.	6900.	7137.	0.	193.	7.	44.
2	289	6	2	1	3	18	6942.	7351.	7351.	7857.	407.	506.	409.	0.
1	290	16	17	1	7	14	6976.	6993.	6991.	7114.	0.	121.	17.	2.
1	291	2	8	1	9	15	6986.	6994.	6921.	7138.	0.	144.	8.	73.
2	291	4	6	2	1	3	6988.	7402.	7402.	7859.	408.	457.	414.	0.
1	292	15	0	1	4	16	7023.	7023.	7015.	7188.	0.	165.	0.	8.
1	292	23	12	1	10	17	7031.	7043.	6899.	7139.	0.	96.	12.	144.
1	293	1	11	1	11	18	7033.	7044.	6952.	7189.	0.	145.	11.	92.
2	293	4	8	1	2	19	7036.	7428.	7428.	7741.	384.	313.	392.	0.
1	293	7	5	1	12	20	7039.	7044.	7014.	7189.	0.	145.	5.	30.
1	293	15	0	1	14	13	7047.	7047.	6829.	7165.	0.	118.	0.	218.
1	294	2	4	1	15	14	7058.	7062.	6799.	7192.	0.	130.	4.	263.
1	294	13	0	1	13	15	7069.	7069.	7063.	7158.	0.	89.	0.	6.
1	295	11	3	1	8	16	7091.	7094.	7087.	7214.	0.	120.	3.	7.
1	295	14	0	1	7	17	7094.	7114.	7114.	7327.	20.	213.	20.	0.
1	296	11	4	1	5	18	7115.	7134.	7134.	7278.	15.	144.	19.	0.
1	297	0	6	1	6	19	7128.	7137.	7137.	7327.	3.	190.	9.	0.
1	297	3	3	1	9	20	7131.	7138.	7138.	7352.	4.	214.	7.	0.
1	297	5	1	1	10	21	7133.	7139.	7139.	7279.	5.	140.	6.	0.
2	297	9	0	2	2	2	7137.	7505.	7505.	7927.	368.	422.	368.	0.
1	298	1	5	1	13	22	7153.	7158.	7158.	7305.	0.	147.	5.	0.
1	298	16	1	1	14	23	7168.	7169.	7165.	7231.	0.	62.	1.	4.
1	298	20	10	1	4	24	7172.	7188.	7188.	7351.	6.	163.	16.	0.
4	299	18	12	4	1	1	7194.	7206.	7113.	7338.	0.	132.	12.	93.
1	299	23	7	1	11	25	7199.	7206.	7189.	7339.	0.	133.	7.	17.
1	300	5	2	1	12	26	7205.	7207.	7189.	7411.	0.	204.	2.	18.
4	300	10	0	4	1	1	7210.	7338.	7338.	7472.	128.	134.	128.	0.
1	300	18	13	1	8	27	7218.	7231.	7214.	7452.	0.	221.	13.	17.
1	301	13	0	1	14	24	7237.	7237.	7231.	7448.	0.	211.	0.	6.
1	301	14	6	1	15	25	7238.	7244.	7192.	7377.	0.	133.	6.	52.
1	302	4	5	1	5	26	7252.	7278.	7278.	7390.	21.	111.	26.	0.
1	302	5	4	1	10	27	7253.	7279.	7279.	7485.	22.	206.	26.	0.
1	302	7	2	1	13	28	7255.	7305.	7305.	7545.	48.	240.	50.	0.
1	302	22	11	1	7	29	7270.	7327.	7327.	7449.	46.	123.	57.	0.
2	303	4	6	1	1	30	7276.	7663.	7663.	8111.	381.	448.	387.	0.
1	304	13	0	1	6	31	7309.	7327.	7327.	7451.	18.	124.	18.	0.
1	306	5	1	1	11	32	7349.	7350.	7339.	7550.	0.	200.	1.	11.
1	306	5	1	1	4	33	7349.	7351.	7351.	7530.	1.	179.	2.	0.
1	306	14	0	1	9	28	7358.	7358.	7352.	7549.	0.	191.	0.	6.
1	306	19	11	1	15	29	7363.	7377.	7377.	7543.	3.	166.	14.	0.
1	307	7	0	1	5	30	7375.	7390.	7390.	7527.	15.	137.	15.	0.
1	307	22	8	1	12	31	7390.	7411.	7411.	7577.	13.	166.	21.	0.
1	309	0	6	1	14	32	7416.	7448.	7448.	7590.	26.	142.	32.	0.
2	309	23	7	1	2	10	7439.	7741.	7741.	8143.	295.	402.	302.	0.
1	313	5	3	1	6	11	7517.	7520.	7451.	7669.	0.	149.	3.	69.
1	313	6	2	1	7	12	7518.	7520.	7449.	7689.	0.	169.	2.	71.
1	314	12	0	1	4	13	7548.	7548.	7530.	7714.	0.	166.	0.	18.
1	315	12	0	1	5	14	7572.	7572.	7527.	7787.	0.	215.	0.	45.
1	316	12	0	1	8	15	7596.	7596.	7452.	7692.	0.	96.	0.	144.
1	316	22	13	1	9	16	7606.	7619.	7549.	7740.	0.	121.	13.	70.
1	318	0	6	1	10	17	7632.	7638.	7485.	7790.	0.	152.	6.	153.
1	318	23	7	1	11	18	7655.	7662.	7550.	7782.	0.	120.	7.	112.
1	319	13	1	1	6	10	7669.	7670.	7669.	7808.	0.	138.	1.	1.
1	319	21	9	1	12	11	7677.	7686.	7577.	7783.	0.	97.	9.	109.
4	319	22	8	4	1	1	7678.	7686.	7472.	7814.	0.	128.	8.	214.
1	320	12	3	1	7	12	7692.	7695.	7689.	7839.	0.	144.	3.	6.
1	321	11	5	1	4	13	7715.	7720.	7714.	7878.	0.	158.	5.	6.
4	321	15	1	4	1	1	7719.	7814.	7814.	7913.	94.	98.	95.	0.
1	322	2	4	1	8	14	7730.	7734.	7692.	7806.	0.	72.	4.	42.
3	323	11	0	3	1	0	7763.	7763.	6834.	7903.	0.	140.	0.	929.
1	324	10	0	1	9	0	7786.	7786.	7740.	7915.	0.	129.	0.	46.
1	324	14	5	1	5	1	7790.	7795.	7787.	7951.	0.	156.	5.	8.
2	325	2	6	1	3	1	7802.	7857.	7857.	8174.	49.	317.	55.	0.

4	325	9	0	4	1	2	7809.	7913.	7913.	8048.	104.	136.	104.	0.
1	325	19	13	1	6	2	7819.	7832.	7808.	8000.	0.	168.	13.	24.
4	326	6	3	4	1	2	7830.	8048.	8048.	8229.	215.	181.	218.	0.
1	326	7	2	1	8	3	7831.	7833.	7806.	8002.	0.	169.	2.	27.
1	326	13	0	1	10	4	7837.	7837.	7790.	8025.	0.	188.	0.	47.
1	326	15	6	1	7	5	7839.	7845.	7839.	8002.	0.	157.	6.	6.
1	326	20	13	1	11	6	7844.	7857.	7782.	7990.	0.	133.	13.	75.
1	327	1	9	1	12	7	7849.	7858.	7783.	8003.	0.	145.	9.	75.
1	327	3	7	1	13	8	7851.	7858.	7545.	8002.	0.	144.	7.	313.
1	327	3	7	1	14	9	7851.	7858.	7590.	8015.	0.	157.	7.	268.
1	327	4	6	1	15	10	7852.	7858.	7543.	8029.	0.	171.	6.	315.
1	329	4	8	1	4	1	7900.	7908.	7878.	8005.	0.	97.	8.	30.
2	329	14	0	2	1	0	7910.	7910.	7859.	8293.	0.	383.	0.	51.
1	329	18	18	1	9	1	7914.	7932.	7915.	8101.	0.	169.	18.	17.
1	330	23	7	1	5	1	7943.	7951.	7951.	8118.	1.	167.	8.	0.
1	331	12	2	1	11	1	7956.	7990.	7990.	8223.	32.	233.	34.	0.
1	331	13	1	1	6	2	7957.	8000.	8000.	8174.	42.	174.	43.	0.
1	331	14	0	1	8	3	7958.	8002.	8002.	8105.	44.	103.	44.	0.
1	331	22	8	1	7	4	7966.	8002.	8002.	8191.	28.	189.	36.	0.
1	332	3	3	1	13	5	7971.	8002.	8002.	8151.	28.	149.	31.	0.
1	332	4	2	1	12	6	7972.	8003.	8003.	8152.	29.	149.	31.	0.
4	333	1	5	4	1	2	7993.	8229.	8229.	8392.	231.	163.	236.	0.
1	333	5	1	1	4	6	7997.	8005.	8005.	8105.	7.	100.	8.	0.
1	333	6	0	1	14	7	7998.	8015.	8015.	8142.	17.	128.	17.	0.
1	334	7	0	1	10	1	8023.	8025.	8025.	8194.	2.	169.	2.	0.
2	334	11	6	2	2	1	8027.	8033.	7927.	8489.	0.	456.	6.	106.
3	334	11	6	3	1	1	8027.	8033.	7903.	8166.	0.	133.	6.	130.
2	335	0	6	1	1	1	8040.	8111.	8111.	8459.	65.	348.	71.	0.
1	335	16	14	1	15	2	8056.	8070.	8029.	8288.	0.	218.	14.	41.
1	335	22	8	1	9	3	8062.	8101.	8101.	8238.	31.	137.	39.	0.
1	336	3	4	1	4	4	8067.	8105.	8105.	8239.	34.	135.	38.	0.
1	336	17	14	1	8	5	8081.	8105.	8105.	8311.	10.	206.	24.	0.
2	336	17	14	1	2	6	8081.	8143.	8143.	8743.	48.	601.	62.	0.
1	337	8	0	1	5	7	8096.	8118.	8118.	8216.	22.	98.	22.	0.
1	337	11	0	1	14	8	8099.	8142.	8142.	8336.	43.	194.	43.	0.
1	338	19	14	1	13	4	8131.	8151.	8151.	8342.	6.	191.	20.	0.
1	339	10	0	1	12	2	8146.	8152.	8152.	8339.	6.	187.	6.	0.
1	339	21	13	1	3	1	8157.	8174.	8174.	8362.	4.	188.	17.	0.
1	339	22	12	1	6	2	8158.	8174.	8174.	8315.	4.	140.	16.	0.
1	340	2	9	1	7	3	8162.	8191.	8191.	8392.	20.	201.	29.	0.
1	340	3	8	1	10	4	8163.	8194.	8194.	8387.	23.	193.	31.	0.
1	340	19	16	1	5	3	8179.	8216.	8216.	8412.	21.	195.	37.	0.
1	341	4	8	1	11	4	8188.	8223.	8223.	8318.	27.	95.	35.	0.
1	342	4	2	1	9	3	8212.	8238.	8238.	8414.	24.	176.	26.	0.
1	344	2	4	1	4	1	8258.	8262.	8239.	8383.	0.	121.	4.	23.
1	345	18	12	1	15	1	8298.	8310.	8288.	8430.	0.	120.	12.	22.
2	345	18	12	2	1	1	8298.	8310.	8293.	8800.	0.	490.	12.	17.
1	346	13	4	1	6	1	8317.	8321.	8315.	8503.	0.	182.	4.	6.
1	347	1	5	1	8	1	8329.	8334.	8311.	8502.	0.	168.	5.	23.
1	348	2	5	1	11	1	8354.	8359.	8318.	8516.	0.	157.	5.	41.
1	348	22	9	1	3	1	8374.	8383.	8362.	8552.	0.	169.	9.	21.
1	350	18	15	1	4	1	8418.	8433.	8383.	8649.	0.	216.	15.	50.
1	350	18	15	1	5	2	8418.	8433.	8412.	8625.	0.	192.	15.	21.
1	351	9	1	1	7	1	8433.	8434.	8392.	8675.	0.	241.	1.	42.
1	351	10	0	1	9	0	8434.	8434.	8414.	8674.	0.	240.	0.	20.
1	351	11	0	1	10	0	8435.	8435.	8387.	8578.	0.	143.	0.	48.
1	351	12	0	1	12	0	8436.	8436.	8339.	8535.	0.	99.	0.	97.
1	352	15	0	1	1	0	8463.	8463.	8459.	8555.	0.	92.	0.	4.
1	352	19	16	1	13	1	8467.	8483.	8342.	8627.	0.	144.	16.	141.
4	353	12	0	4	1	0	8484.	8484.	8392.	8628.	0.	144.	0.	92.
1	354	5	1	1	14	1	8501.	8502.	8336.	8677.	0.	175.	1.	166.
1	354	8	5	1	6	1	8504.	8509.	8503.	8743.	0.	234.	5.	6.
1	354	8	5	1	8	2	8504.	8509.	8502.	8646.	0.	137.	5.	7.
1	355	8	6	1	11	1	8528.	8534.	8516.	8704.	0.	170.	6.	18.
1	355	11	3	1	15	2	8531.	8534.	8430.	8767.	0.	233.	3.	104.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	355	15	0	1	12	1	8535.	8535.	8535.	8654.	0.	119.	0.	0.
1	355	20	10	1	3	1	8540.	8552.	8552.	8678.	2.	127.	12.	0.
2	356	7	0	1	1	2	8551.	8555.	8555.	8887.	4.	331.	4.	0.
1	356	15	0	1	10	1	8559.	8578.	8578.	8728.	19.	149.	19.	0.
1	357	12	4	1	5	1	8580.	8625.	8625.	8767.	41.	142.	45.	0.
3	359	4	2	3	1	1	8620.	8622.	8166.	8839.	0.	217.	2.	456.
3	359	7	0	3	1	1	8623.	8839.	8839.	9078.	216.	240.	216.	0.
4	360	3	4	4	1	1	8643.	8647.	8628.	8816.	0.	169.	4.	19.
1	360	7	0	1	8	0	8647.	8647.	8646.	8743.	0.	96.	0.	1.
1	361	17	15	1	3	1	8681.	8696.	8678.	8918.	0.	222.	15.	18.
1	361	19	13	1	4	2	8683.	8696.	8649.	8865.	0.	169.	13.	47.
4	363	8	2	4	1	1	8720.	8816.	8816.	9038.	94.	222.	96.	0.
1	363	15	0	1	7	0	8727.	8727.	8675.	8820.	0.	93.	0.	52.
2	365	7	5	1	2	1	8767.	8772.	8743.	9157.	0.	385.	5.	29.
1	365	11	1	1	5	2	8771.	8772.	8767.	8892.	0.	120.	1.	5.
1	365	16	0	1	6	0	8776.	8776.	8743.	8917.	0.	141.	0.	33.
1	365	19	17	1	8	1	8779.	8796.	8743.	8964.	0.	168.	17.	53.
1	365	20	16	1	9	2	8780.	8796.	8674.	8893.	0.	97.	16.	122.
1	366	0	6	1	10	3	8784.	8790.	8728.	8886.	0.	96.	6.	62.
2	366	4	2	2	1	1	8788.	8800.	8800.	9078.	10.	278.	12.	0.
4	366	5	1	4	1	2	8789.	9038.	9038.	9198.	248.	160.	249.	0.
2	367	18	12	1	1	1	8826.	8887.	8887.	9254.	49.	368.	61.	0.
1	368	7	0	1	7	2	8839.	8839.	8820.	9030.	0.	191.	0.	19.
1	368	8	0	1	11	3	8840.	8840.	8704.	8968.	0.	128.	0.	136.
2	368	14	1	1	3	4	8846.	8918.	8918.	9318.	71.	400.	72.	0.
4	368	14	1	4	1	2	8846.	9198.	9198.	9390.	351.	192.	352.	0.
1	369	8	0	1	12	5	8864.	8864.	8654.	9082.	0.	218.	0.	210.
1	369	18	12	1	4	6	8874.	8886.	8865.	9041.	0.	155.	12.	21.
1	370	15	2	1	5	4	8895.	8897.	8892.	9031.	0.	134.	2.	5.
1	370	16	1	1	9	5	8896.	8897.	8893.	9103.	0.	206.	1.	4.
1	371	2	4	1	10	6	8906.	8910.	8886.	9090.	0.	180.	4.	24.
1	371	4	2	1	13	7	8908.	8910.	8627.	9030.	0.	120.	2.	283.
2	371	4	2	2	2	1	8908.	9038.	9038.	9522.	128.	484.	130.	0.
1	371	7	0	1	14	8	8911.	8911.	8677.	9082.	0.	171.	0.	234.
1	371	10	0	1	15	9	8914.	8914.	8767.	9042.	0.	128.	0.	147.
2	371	16	2	2	1	2	8920.	9078.	9078.	9463.	156.	384.	158.	0.
1	371	22	8	1	6	1	8926.	8934.	8917.	9058.	0.	124.	8.	17.
1	372	4	3	1	8	2	8932.	8964.	8964.	9128.	29.	163.	32.	0.
2	373	2	6	1	2	2	8954.	9157.	9157.	9633.	197.	476.	203.	0.
1	375	2	8	1	11	2	9002.	9010.	8968.	9203.	0.	193.	8.	42.
1	375	18	16	1	5	3	9018.	9034.	9031.	9106.	0.	72.	16.	3.
1	376	6	5	1	7	4	9030.	9035.	9030.	9155.	0.	120.	5.	5.
1	376	7	4	1	13	5	9031.	9035.	9030.	9206.	0.	171.	4.	5.
1	376	13	0	1	4	6	9037.	9041.	9041.	9132.	4.	91.	4.	0.
1	378	1	5	1	6	7	9073.	9078.	9058.	9306.	0.	228.	5.	20.
1	378	4	2	1	15	8	9076.	9078.	9042.	9281.	0.	203.	2.	36.
1	378	10	3	1	12	9	9082.	9085.	9082.	9247.	0.	162.	3.	3.
1	378	14	0	1	14	10	9086.	9086.	9082.	9230.	0.	144.	0.	4.
1	379	9	5	1	5	11	9105.	9110.	9106.	9390.	0.	280.	5.	4.
1	379	12	2	1	9	12	9108.	9110.	9103.	9279.	0.	169.	2.	7.
2	380	17	0	1	1	13	9137.	9254.	9254.	9687.	117.	433.	117.	0.
2	381	13	3	1	3	14	9157.	9318.	9318.	9798.	158.	480.	161.	0.
1	381	19	11	1	4	3	9163.	9174.	9132.	9329.	0.	155.	11.	42.
1	381	22	8	1	7	4	9166.	9174.	9155.	9304.	0.	130.	8.	19.
1	385	3	5	1	8	5	9243.	9248.	9128.	9368.	0.	120.	5.	120.
4	385	17	15	4	1	1	9257.	9390.	9390.	9468.	118.	78.	133.	0.
1	385	20	12	1	10	5	9260.	9272.	9090.	9396.	0.	124.	12.	182.
1	386	4	5	1	11	6	9268.	9273.	9203.	9393.	0.	120.	5.	70.
1	386	11	0	1	12	7	9275.	9275.	9247.	9393.	0.	118.	0.	28.
3	386	21	12	3	1	1	9285.	9297.	9078.	9513.	0.	216.	12.	219.
1	387	7	3	1	9	8	9295.	9298.	9279.	9442.	0.	144.	3.	19.
1	387	18	16	1	6	9	9306.	9322.	9306.	9490.	0.	168.	16.	16.
1	388	10	1	1	7	1	9322.	9323.	9304.	9539.	0.	216.	1.	19.
1	388	15	0	1	13	0	9327.	9327.	9206.	9515.	0.	188.	0.	121.
1	390	1	5	1	4	1	9361.	9366.	9329.	9542.	0.	176.	5.	37.
1	390	4	2	1	14	2	9364.	9366.	9230.	9486.	0.	170.	2.	136.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	390	18	12	1	8	1	9378.	9390.	9368.	9582.	0.	192.	12.	22.
1	391	0	6	1	15	2	9384.	9390.	9281.	9544.	0.	154.	6.	109.
1	391	9	5	1	5	1	9393.	9398.	9390.	9606.	0.	208.	5.	8.
4	391	14	0	4	1	1	9398.	9468.	9468.	9615.	70.	147.	70.	0.
1	392	0	6	1	10	1	9408.	9414.	9396.	9544.	0.	130.	6.	18.
1	393	1	5	1	11	1	9433.	9438.	9393.	9607.	0.	169.	5.	45.
1	393	14	2	1	9	1	9446.	9448.	9442.	9606.	0.	158.	2.	6.
1	393	20	10	1	12	1	9452.	9462.	9393.	9607.	0.	145.	10.	69.
1	393	20	10	1	14	2	9452.	9486.	9486.	9678.	24.	192.	34.	0.
2	394	3	3	2	1	1	9459.	9463.	9463.	9943.	1.	480.	4.	0.
2	394	13	4	2	2	1	9469.	9522.	9522.	10002.	49.	479.	53.	0.
1	394	18	12	1	6	2	9474.	9490.	9490.	9569.	4.	79.	16.	0.
1	395	4	2	1	13	3	9484.	9515.	9515.	9774.	29.	259.	31.	0.
1	395	4	2	1	7	4	9484.	9539.	9539.	9714.	53.	175.	55.	0.
1	395	22	8	1	4	3	9502.	9542.	9542.	9714.	32.	172.	40.	0.
4	396	1	6	4	1	1	9505.	9615.	9615.	9751.	104.	136.	110.	0.
1	396	15	4	1	10	3	9519.	9544.	9544.	9682.	21.	138.	25.	0.
1	397	15	5	1	15	2	9543.	9548.	9544.	9729.	0.	181.	5.	4.
2	398	3	6	1	2	1	9555.	9633.	9633.	10047.	72.	414.	78.	0.
1	398	16	5	1	6	2	9568.	9573.	9569.	9682.	0.	109.	5.	4.
1	399	8	2	1	8	3	9584.	9586.	9582.	9731.	0.	145.	2.	4.
1	400	2	9	1	5	4	9602.	9611.	9606.	9779.	0.	168.	9.	5.
1	400	8	3	1	9	5	9608.	9611.	9606.	9756.	0.	145.	3.	5.
1	401	14	0	1	11	0	9638.	9638.	9607.	9805.	0.	167.	0.	31.
1	402	14	0	1	12	0	9662.	9662.	9607.	9775.	0.	113.	0.	55.
1	402	22	8	1	14	1	9670.	9678.	9678.	9846.	0.	168.	8.	0.
1	404	10	5	1	1	1	9706.	9711.	9687.	9897.	0.	186.	5.	24.
1	404	13	2	1	6	2	9709.	9711.	9682.	9882.	0.	171.	2.	29.
1	407	9	0	1	4	0	9777.	9777.	9714.	10014.	0.	237.	0.	63.
1	407	10	0	1	7	0	9778.	9778.	9714.	9894.	0.	116.	0.	64.
1	407	17	13	1	5	1	9785.	9798.	9779.	10016.	0.	218.	13.	19.
1	408	1	6	1	3	2	9793.	9799.	9798.	9895.	0.	96.	6.	1.
2	409	3	5	1	3	1	9819.	9895.	9895.	10425.	71.	530.	76.	0.
1	410	4	5	1	8	2	9844.	9849.	9731.	10042.	0.	193.	5.	118.
3	410	6	3	3	1	1	9846.	9849.	9513.	10113.	0.	264.	3.	336.
1	410	14	0	1	9	3	9854.	9854.	9756.	10018.	0.	164.	0.	98.
1	410	16	17	1	10	4	9856.	9873.	9682.	10066.	0.	193.	17.	191.
1	410	20	13	1	11	5	9860.	9873.	9805.	10066.	0.	193.	13.	68.
1	411	2	8	1	12	6	9866.	9874.	9775.	10042.	0.	168.	8.	99.
1	411	6	4	1	13	7	9870.	9874.	9774.	10090.	0.	216.	4.	100.
1	412	2	9	1	1	8	9890.	9899.	9897.	10044.	0.	145.	9.	2.
1	413	1	11	1	6	1	9913.	9924.	9882.	10116.	0.	192.	11.	42.
2	415	0	6	2	1	1	9960.	9966.	9943.	10447.	0.	481.	6.	23.
1	415	1	5	1	7	1	9961.	9966.	9894.	10071.	0.	105.	5.	72.
1	415	17	0	1	14	0	9977.	9977.	9846.	10134.	0.	157.	0.	131.
1	417	13	3	1	4	1	10021.	10024.	10014.	10233.	0.	209.	3.	10.
2	417	16	0	2	2	0	10024.	10024.	10002.	10471.	0.	447.	0.	22.
2	418	4	2	1	1	1	10036.	10044.	10044.	10434.	6.	390.	8.	0.
1	418	19	11	1	2	1	10051.	10062.	10047.	10230.	0.	168.	11.	15.
1	419	5	1	1	5	2	10061.	10062.	10016.	10210.	0.	148.	1.	46.
1	419	9	0	1	8	0	10065.	10065.	10042.	10255.	0.	190.	0.	23.
1	419	13	5	1	7	1	10069.	10074.	10071.	10182.	0.	108.	5.	3.
1	419	23	7	1	9	1	10079.	10086.	10018.	10206.	0.	120.	7.	68.
1	420	9	0	1	10	0	10089.	10089.	10066.	10231.	0.	142.	0.	23.
4	420	22	9	4	1	1	10102.	10111.	9751.	10211.	0.	100.	9.	360.
1	422	0	9	1	6	1	10128.	10137.	10116.	10305.	0.	168.	9.	21.
1	422	23	10	1	11	1	10151.	10161.	10066.	10281.	0.	120.	10.	95.
2	423	0	10	1	2	2	10152.	10230.	10230.	10546.	68.	316.	78.	0.
1	423	6	4	1	12	3	10158.	10162.	10042.	10427.	0.	265.	4.	120.
1	423	16	6	1	13	3	10168.	10174.	10090.	10285.	0.	111.	6.	84.
1	423	23	11	1	7	4	10175.	10186.	10182.	10356.	0.	170.	11.	4.
1	424	18	17	1	5	5	10194.	10211.	10210.	10355.	0.	144.	17.	1.
2	425	7	5	1	3	6	10207.	10425.	10425.	10933.	213.	508.	218.	0.
1	425	15	0	1	9	7	10215.	10215.	10206.	10332.	0.	117.	0.	9.
2	425	20	16	1	1	8	10220.	10434.	10434.	10933.	198.	499.	214.	0.
1	426	1	5	1	14	9	10225.	10230.	10134.	10470.	0.	240.	5.	[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	426	12	1	2	1	110236.	10447.10447.10878.	210.	432.	211.	0.
1	427	4	2	1	4	510252.	10254.10233.10407.	0.	153.	2.	21.
1	427	15	0	1	8	610263.	10263.10255.10423.	0.	160.	0.	8.
4	427	21	9	4	1	110269.	10278.10211.10455.	0.	177.	9.	67.
1	428	13	2	1	10	710285.	10287.10231.10431.	0.	144.	2.	56.
1	428	16	0	1	11	810288.	10288.10281.10432.	0.	144.	0.	7.
1	429	9	0	1	13	910305.	10305.10285.10446.	0.	141.	0.	20.
1	430	3	3	1	6	1010323.	10326.10305.10567.	0.	241.	3.	21.
1	431	3	3	1	9	1110347.	10350.10332.10547.	0.	197.	3.	18.
1	431	7	0	1	15	1210351.	10351. 9729.10496.	0.	145.	0.	622.
1	431	11	0	1	5	1310355.	10355.10355.10521.	0.	166.	0.	0.
3	431	13	17	3	1	110357.	10374.10113.10499.	0.	125.	17.	261.
1	431	20	10	1	7	1410364.	10374.10356.10543.	0.	169.	10.	18.
4	431	23	7	4	1	110367.	10455.10455.10614.	81.	159.	88.	0.
2	432	18	13	2	2	210386.	10471.10471.10907.	72.	436.	85.	0.
1	432	19	12	1	4	1510387.	10407.10407.10616.	8.	208.	20.	0.
1	434	15	18	1	8	1410431.	10449.10423.10669.	0.	220.	18.	26.
1	435	16	18	1	10	110456.	10474.10431.10643.	0.	169.	18.	43.
1	435	20	14	1	11	210460.	10474.10432.10667.	0.	193.	14.	42.
1	436	2	9	1	12	310466.	10475.10427.10620.	0.	145.	9.	48.
1	436	8	3	1	13	410472.	10475.10446.10649.	0.	174.	3.	29.
1	437	16	0	1	14	010504.	10504.10470.10693.	0.	189.	0.	34.
1	439	4	2	1	5	110540.	10542.10521.10663.	0.	121.	2.	21.
1	439	19	11	1	2	110555.	10566.10546.10759.	0.	193.	11.	20.
1	439	21	9	1	7	210557.	10566.10543.10743.	0.	177.	9.	23.
1	441	1	5	1	6	110585.	10590.10567.10831.	0.	241.	5.	23.
1	441	9	0	1	9	010593.	10593.10547.10737.	0.	144.	0.	46.
2	441	10	6	1	2	110594.	10759.10759.11287.	159.	528.	165.	0.
1	441	15	1	1	15	210599.	10600.10496.10768.	0.	168.	1.	104.
2	441	16	0	2	1	110600.	10878.10878.11416.	278.	538.	278.	0.
1	441	22	8	1	4	310606.	10616.10616.10769.	2.	153.	10.	0.
1	443	7	0	1	12	410639.	10639.10620.10762.	0.	123.	0.	19.
1	444	0	7	1	5	510656.	10663.10663.10834.	0.	171.	7.	0.
2	444	11	0	2	2	210667.	10907.10907.11360.	240.	452.	240.	0.
1	444	17	2	1	8	610673.	10675.10669.10837.	0.	162.	2.	6.
1	445	14	6	1	10	710694.	10700.10643.10929.	0.	229.	6.	57.
1	445	20	12	1	11	810700.	10712.10667.10880.	0.	168.	12.	45.
2	446	0	9	1	3	910704.	10933.10933.11494.	220.	561.	229.	0.
2	446	5	4	1	1	1010709.	10933.10933.11435.	220.	502.	224.	0.
2	446	12	0	1	2	1110716.	11287.11287.11721.	571.	434.	571.	0.
1	446	19	14	1	9	1210723.	10737.10737.10786.	0.	49.	14.	0.
1	447	2	8	1	13	1310730.	10738.10649.10883.	0.	145.	8.	89.
1	448	3	8	1	7	1410755.	10763.10743.10955.	0.	192.	8.	20.
1	448	15	0	1	12	710767.	10767.10762.10955.	0.	188.	0.	5.
1	448	15	0	1	14	810767.	10767.10693.10956.	0.	189.	0.	74.
1	448	19	16	1	4	910771.	10787.10769.10979.	0.	192.	16.	18.
1	448	22	13	1	9	1010774.	10787.10786.10937.	0.	150.	13.	1.
1	448	23	12	1	15	1110775.	10787.10768.10932.	0.	145.	12.	19.
1	450	0	6	1	6	1210800.	10831.10831.10998.	25.	167.	31.	0.
1	450	1	5	1	5	1310801.	10834.10834.10998.	28.	164.	33.	0.
1	450	7	6	1	8	1410807.	10837.10837.11030.	24.	193.	30.	0.
1	450	21	9	1	11	1510821.	10880.10880.11054.	50.	174.	59.	0.
2	450	23	7	2	2	310823.	11360.11360.11839.	530.	479.	537.	0.
2	451	16	0	2	1	410840.	11416.11416.11944.	576.	527.	576.	0.
1	451	21	9	1	13	1610845.	10883.10883.11095.	29.	212.	38.	0.
1	451	22	8	1	10	1710846.	10929.10929.11031.	75.	102.	83.	0.
1	452	3	3	1	15	1810851.	10932.10932.11033.	78.	102.	81.	0.
1	452	10	5	1	9	1910858.	10937.10937.11070.	74.	133.	79.	0.
1	453	18	12	1	12	2010890.	10955.10955.11071.	53.	115.	65.	0.
1	453	23	7	1	7	2110895.	10955.10955.11119.	53.	163.	60.	0.
2	454	4	2	1	1	2210900.	11435.11435.11778.	533.	343.	535.	0.
1	454	7	0	1	14	2310903.	10956.10956.11047.	53.	91.	53.	0.
1	455	4	2	1	4	2410924.	10979.10979.11143.	53.	164.	55.	0.
1	455	21	9	1	5	2310941.	10998.10998.11215.	48.	217.	57.	0.
2	456	1	6	1	3	2410945.	11494.11494.11983.	543.	490.	549.	0.
1	456	6	1	1	6	2510950.	10998.10998.11216.	47.	217.	48.	0.

1	456	23	8	1	8	2610967.	11030.11030.11239.	55.	210.	63.	0.
1	457	1	7	1	10	2710969.	11031.11031.11121.	55.	90.	62.	0.
2	457	2	6	1	2	2810970.	11721.11721.12153.	745.	432.	751.	0.
1	458	20	13	1	15	2911012.	11033.11033.11289.	8.	256.	21.	0.
1	458	21	12	1	14	3011013.	11047.11047.11150.	22.	104.	34.	0.
1	459	0	10	1	11	3111016.	11054.11054.11315.	28.	261.	38.	0.
1	459	3	7	1	9	3211019.	11070.11070.11243.	44.	173.	51.	0.
1	459	20	14	1	12	3311036.	11071.11071.11219.	21.	148.	35.	0.
1	462	1	5	1	13	3411089.	11095.11095.11269.	1.	175.	6.	0.
1	462	6	0	1	7	3511094.	11119.11119.11246.	25.	128.	25.	0.
4	462	16	0	4	1	011104.	11104.10614.11321.	0.	217.	0.	490.
1	463	11	3	1	10	3611123.	11126.11121.11335.	0.	209.	3.	5.
1	464	1	5	1	4	3711137.	11143.11143.11335.	1.	192.	6.	0.
1	464	2	4	1	14	3811138.	11150.11150.11311.	8.	160.	12.	0.
1	464	20	10	1	5	3911156.	11215.11215.11406.	49.	191.	59.	0.
1	465	3	3	1	6	4011163.	11216.11216.11369.	50.	153.	53.	0.
1	465	12	4	1	12	4111172.	11219.11219.11393.	43.	174.	47.	0.
1	465	12	4	1	8	4211172.	11239.11239.11336.	63.	97.	67.	0.
1	466	6	0	1	9	4311190.	11243.11243.11358.	53.	115.	53.	0.
4	467	6	0	4	1	111214.	11321.11321.11459.	107.	138.	107.	0.
1	467	9	0	1	7	4411217.	11246.11246.11383.	29.	136.	29.	0.
1	467	15	3	1	13	4511223.	11269.11269.11435.	43.	166.	46.	0.
1	467	23	7	1	15	4611231.	11289.11289.11479.	51.	190.	58.	0.
1	468	5	2	1	14	4711237.	11311.11311.11432.	72.	121.	74.	0.
1	468	10	0	1	11	4811242.	11315.11315.11527.	73.	213.	73.	0.
1	468	10	0	1	4	4911242.	11335.11335.11455.	93.	121.	93.	0.
1	468	12	0	1	10	5011244.	11335.11335.11527.	91.	193.	91.	0.
1	471	11	0	1	8	3211315.	11336.11336.11555.	21.	218.	21.	0.
1	472	15	0	1	9	3311343.	11358.11358.11556.	15.	197.	15.	0.
1	472	19	16	1	6	3411347.	11369.11369.11436.	6.	67.	22.	0.
1	473	9	3	1	7	3511361.	11383.11383.11628.	19.	246.	22.	0.
1	473	17	0	1	12	3611369.	11393.11393.11533.	24.	140.	24.	0.
4	474	1	5	4	1	111377.	11459.11459.11679.	77.	219.	82.	0.
1	474	23	7	1	5	3711399.	11406.11406.11550.	0.	144.	7.	0.
1	476	1	5	1	14	3811425.	11432.11432.11647.	2.	215.	7.	0.
2	476	19	11	1	1	3511443.	11778.11778.12078.	324.	301.	335.	0.
2	478	6	0	2	2	111478.	11839.11839.12438.	361.	599.	361.	0.
3	478	13	4	3	1	111485.	11489.10499.11682.	0.	193.	4.	990.
1	479	2	4	1	4	3211498.	11502.11455.11598.	0.	96.	4.	47.
1	480	1	6	1	6	3311521.	11527.11436.11695.	0.	168.	6.	91.
2	480	10	0	2	1	211530.	11944.11944.12469.	414.	525.	414.	0.
4	481	16	16	4	1	111560.	11679.11679.11888.	103.	210.	119.	0.
1	483	5	5	1	4	3411597.	11602.11598.11746.	0.	144.	5.	4.
1	483	6	4	1	5	3511598.	11602.11550.11747.	0.	145.	4.	52.
2	484	1	10	1	3	3611617.	11983.11983.12443.	356.	460.	366.	0.
2	484	7	4	1	1	3711623.	12078.12078.12564.	451.	485.	455.	0.
2	485	0	12	1	2	3811640.	12153.12153.12661.	501.	508.	513.	0.
1	485	5	7	1	7	3911645.	11652.11628.11845.	0.	193.	7.	24.
1	485	10	2	1	8	4011650.	11652.11555.11800.	0.	148.	2.	97.
1	485	23	13	1	9	4111663.	11676.11556.11845.	0.	169.	13.	120.
1	486	3	3	1	10	4211667.	11670.11527.11839.	0.	169.	3.	143.
1	486	14	0	1	11	4311678.	11678.11527.11863.	0.	185.	0.	151.
2	487	2	4	2	2	311690.	12438.12438.12711.	744.	273.	748.	0.
1	487	4	2	1	12	4411692.	11694.11533.11790.	0.	96.	2.	161.
2	488	13	2	1	3	1511725.	12443.12443.12846.	716.	403.	718.	0.
1	488	19	11	1	6	1611731.	11742.11695.11887.	0.	145.	11.	47.
2	488	22	8	2	1	411734.	12469.12469.13087.	727.	618.	735.	0.
1	489	6	0	1	13	1711742.	11742.11435.11872.	0.	130.	0.	307.
1	489	10	6	1	4	1811746.	11752.11746.11945.	0.	193.	6.	6.
1	489	12	4	1	5	1911748.	11752.11747.11958.	0.	206.	4.	5.
1	489	17	0	1	14	2011753.	11753.11647.11935.	0.	182.	0.	106.
1	491	16	2	1	8	1611800.	11802.11800.11922.	0.	120.	2.	2.
1	491	18	12	1	12	1711802.	11814.11790.12031.	0.	217.	12.	24.
1	492	1	6	1	15	1811809.	11815.11479.12032.	0.	217.	6.	336.
1	492	15	4	1	10	1911823.	11839.11839.12032.	12.	193.	16.	0.
4	493	14	6	4	1	111846.	11888.11888.11961.	34.	72.	42.	0.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2 494	2	7	1	1	2011858.	12564.12564.13017.	699.	454.	706.	0.
1 494	11	0	1	7	2111867.	11867.11845.12046.	0.	179.	0.	22.
1 494	20	13	1	6	2211876.	11889.11887.12009.	0.	120.	13.	2.
1 497	6	6	1	8	2311934.	11940.11922.12108.	0.	168.	6.	18.
1 497	22	14	1	4	2411950.	11964.11945.12065.	0.	101.	14.	19.
1 498	12	1	1	5	2511964.	11965.11958.12113.	0.	148.	1.	7.
1 498	16	0	1	9	2611968.	11968.11845.12103.	0.	135.	0.	123.
1 498	17	0	1	11	2711969.	11969.11863.12157.	0.	188.	0.	106.
1 501	9	0	1	6	2712033.	12033.12009.12232.	0.	199.	0.	24.
1 501	19	11	1	7	2812043.	12054.12046.12224.	0.	170.	11.	8.
1 501	19	11	1	10	2912043.	12054.12032.12271.	0.	217.	11.	22.
4 502	1	5	4	1	112049.	12054.11961.12174.	0.	120.	5.	93.
1 502	18	12	1	4	3012066.	12078.12065.12296.	0.	218.	12.	13.
1 504	18	13	1	5	3012114.	12127.12113.12391.	0.	264.	13.	14.
3 504	22	9	3	1	112118.	12127.11682.12343.	0.	216.	9.	445.
1 505	13	0	1	8	3112133.	12133.12108.12224.	0.	91.	0.	25.
4 505	17	15	4	1	112137.	12174.12174.12297.	22.	122.	37.	0.
1 506	2	7	1	9	3212146.	12153.12103.12394.	0.	241.	7.	50.
1 506	4	5	1	12	3312148.	12153.12031.12298.	0.	145.	5.	122.
1 507	15	0	1	11	2712183.	12183.12157.12346.	0.	163.	0.	26.
1 508	15	0	1	13	2812207.	12207.11872.12347.	0.	140.	0.	335.
2 510	20	10	1	2	2912260.	12661.12661.12918.	391.	257.	401.	0.
1 513	8	0	1	4	3012320.	12320.12296.12486.	0.	166.	0.	24.
2 513	14	2	2	2	312326.	12711.12711.13110.	383.	400.	385.	0.
1 513	22	8	1	6	3112334.	12342.12232.12545.	0.	203.	8.	110.
1 514	0	6	1	7	3212336.	12342.12224.12534.	0.	192.	6.	118.
1 515	0	6	1	8	3312360.	12366.12224.12570.	0.	204.	6.	142.
1 515	8	0	1	10	3412368.	12368.12271.12516.	0.	148.	0.	97.
1 515	9	0	1	11	3512369.	12369.12346.12486.	0.	117.	0.	23.
1 516	4	3	1	12	3612388.	12391.12298.12560.	0.	169.	3.	93.
2 516	11	0	1	3	3712395.	12846.12846.13244.	451.	398.	451.	0.
1 516	18	13	1	5	3812402.	12415.12391.12644.	0.	229.	13.	24.
1 516	19	12	1	9	3912403.	12415.12394.12632.	0.	217.	12.	21.
1 517	3	5	1	13	4012411.	12416.12347.12561.	0.	145.	5.	69.
1 517	5	3	1	14	4112413.	12416.11935.12621.	0.	205.	3.	481.
1 517	11	0	1	15	4212419.	12419.12032.12608.	0.	189.	0.	387.
1 517	12	0	1	11	4312420.	12486.12486.12620.	66.	134.	66.	0.
1 517	22	10	1	4	4412430.	12486.12486.12609.	46.	123.	56.	0.
1 518	4	5	1	10	4512436.	12516.12516.12610.	75.	94.	80.	0.
1 518	6	3	1	7	4612438.	12534.12534.12645.	93.	111.	96.	0.
1 518	7	2	1	6	4712439.	12545.12545.12681.	104.	136.	106.	0.
1 518	12	0	1	12	3812444.	12560.12560.12634.	116.	74.	116.	0.
1 518	20	13	1	13	3912452.	12561.12561.12753.	96.	192.	109.	0.
2 519	9	1	1	2	4012465.	12918.12918.13283.	452.	365.	453.	0.
2 519	13	0	1	1	4112469.	13017.13017.13355.	548.	338.	548.	0.
1 520	3	8	1	8	4212483.	12570.12570.12737.	79.	166.	87.	0.
1 520	22	13	1	15	4312502.	12608.12608.12731.	93.	123.	106.	0.
4 521	9	3	4	1	112513.	12516.12297.12685.	0.	169.	3.	219.
1 521	21	15	1	4	4412525.	12609.12609.12684.	69.	75.	84.	0.
1 523	7	0	1	10	4512559.	12610.12610.12750.	51.	140.	51.	0.
1 524	13	2	1	11	2812589.	12620.12620.12784.	29.	164.	31.	0.
1 524	14	1	1	14	2912590.	12621.12621.12750.	30.	130.	31.	0.
1 525	5	1	1	9	3012605.	12632.12632.12823.	26.	191.	27.	0.
1 526	8	0	1	12	3112632.	12634.12634.12774.	2.	140.	2.	0.
1 526	13	4	1	5	3212637.	12644.12644.12785.	3.	142.	7.	0.
2 526	22	8	2	1	212646.	13087.13087.13494.	433.	408.	441.	0.
1 527	4	2	1	7	3312652.	12654.12645.12846.	0.	192.	2.	9.
4 528	4	3	4	1	112676.	12685.12685.12848.	6.	163.	9.	0.
1 529	10	0	1	4	2612706.	12706.12684.12873.	0.	167.	0.	22.
1 529	13	0	1	6	2712709.	12709.12681.12875.	0.	166.	0.	28.
1 529	21	11	1	15	2812717.	12731.12731.12897.	3.	165.	14.	0.
1 530	20	13	1	8	2912740.	12753.12737.12946.	0.	193.	13.	16.
1 530	21	12	1	10	3012741.	12753.12750.12900.	0.	147.	12.	3.
1 531	3	7	1	13	3112747.	12754.12753.12970.	0.	216.	7.	1.
2 531	17	17	2	2	212761.	13110.13110.13455.	332.	345.	349.	0.
1 533	3	9	1	5	3212795.	12804.12785.12901.	0.	97.	9.	19.

1	533	12	0	1	11	3312804.	12804.12784.12996.	0.	192.	0.	20.
1	534	6	0	1	12	3412822.	12822.12774.12950.	0.	128.	0.	48.
1	535	7	0	1	7	2212847.	12847.12846.13015.	0.	168.	0.	1.
1	536	7	0	1	9	2312871.	12871.12823.12990.	0.	119.	0.	48.
1	536	8	0	1	14	2412872.	12872.12750.12999.	0.	127.	0.	122.
1	536	11	4	1	4	2512875.	12879.12873.13071.	0.	192.	4.	6.
1	536	20	10	1	6	2612884.	12894.12875.13038.	0.	144.	10.	19.
1	538	11	6	1	5	2612923.	12929.12901.13097.	0.	168.	6.	28.
1	539	6	0	1	10	2712942.	12942.12900.13087.	0.	145.	0.	42.
2	539	20	10	1	3	2812956.	13244.13244.13602.	278.	358.	288.	0.
1	540	4	3	1	8	2912964.	12967.12946.13140.	0.	173.	3.	21.
1	540	19	12	1	9	3012979.	12991.12990.13139.	0.	148.	12.	1.
2	541	3	5	1	2	3112987.	13283.13283.13929.	291.	645.	296.	0.
1	542	15	6	1	7	513023.	13029.13015.13161.	0.	132.	6.	14.
1	544	9	2	1	6	613065.	13067.13038.13284.	0.	217.	2.	29.
1	545	7	5	1	4	713087.	13092.13071.13312.	0.	220.	5.	21.
1	545	10	2	1	10	813090.	13092.13087.13189.	0.	97.	2.	5.
1	545	22	14	1	5	913102.	13116.13097.13240.	0.	124.	14.	19.
1	546	10	3	1	11	1013114.	13117.12996.13334.	0.	217.	3.	121.
2	547	12	2	1	1	1113140.	13355.13355.13912.	213.	557.	215.	0.
1	547	19	11	1	8	1213147.	13158.13140.13326.	0.	168.	11.	18.
1	548	13	2	1	7	1313165.	13167.13161.13335.	0.	168.	2.	6.
1	550	5	1	1	9	1413205.	13206.13139.13375.	0.	169.	1.	67.
4	550	22	8	4	1	113222.	13230.12848.13423.	0.	193.	8.	382.
1	553	11	0	1	5	1213283.	13283.13240.13448.	0.	165.	0.	43.
2	553	15	17	2	2	113287.	13455.13455.13881.	151.	425.	168.	0.
1	553	17	15	1	6	613289.	13304.13284.13449.	0.	145.	15.	20.
1	553	19	13	1	10	713291.	13304.13189.13379.	0.	75.	13.	115.
1	554	13	0	1	12	813309.	13309.12950.13478.	0.	169.	0.	359.
1	555	6	4	1	4	913326.	13330.13312.13474.	0.	144.	4.	18.
1	555	6	4	1	8	1013326.	13330.13326.13474.	0.	144.	4.	4.
1	555	8	2	1	13	1113328.	13330.12970.13429.	0.	99.	2.	360.
1	555	19	15	1	7	1213339.	13354.13335.13475.	0.	121.	15.	19.
2	556	22	13	2	1	213366.	13494.13494.13883.	115.	389.	128.	0.
1	557	10	2	1	9	113378.	13380.13375.13548.	0.	168.	2.	5.
1	557	21	15	1	10	113389.	13404.13379.13548.	0.	144.	15.	25.
1	558	7	6	1	11	213399.	13405.13334.13615.	0.	210.	6.	71.
1	559	7	0	1	14	013423.	13423.12999.13519.	0.	96.	0.	424.
1	559	16	0	1	13	013432.	13432.13429.13574.	0.	142.	0.	3.
2	560	6	0	1	3	113446.	13602.13602.14178.	156.	576.	156.	0.
1	560	10	5	1	5	213450.	13455.13448.13648.	0.	193.	5.	7.
1	561	1	5	1	6	313465.	13470.13449.13567.	0.	97.	5.	21.
1	561	10	6	1	4	413474.	13480.13474.13624.	0.	144.	6.	6.
1	561	14	2	1	7	513478.	13480.13475.13662.	0.	182.	2.	5.
1	562	4	2	1	8	613492.	13494.13474.13642.	0.	148.	2.	20.
1	562	6	0	1	12	713494.	13494.13478.13710.	0.	216.	0.	16.
1	562	14	3	1	15	813502.	13505.12897.13638.	0.	133.	3.	608.
1	562	20	10	1	14	913508.	13519.13519.13687.	1.	168.	11.	0.
1	563	7	0	1	10	1013519.	13548.13548.13663.	29.	115.	29.	0.
1	563	11	0	1	9	1113523.	13548.13548.13675.	25.	126.	25.	0.
1	565	4	4	1	6	1213564.	13568.13567.13797.	0.	229.	4.	1.
1	565	4	4	1	13	1313564.	13574.13574.13785.	6.	211.	10.	0.
1	565	17	3	1	11	1413577.	13615.13615.13808.	35.	194.	38.	0.
1	565	18	14	1	4	1513578.	13624.13624.13761.	32.	136.	46.	0.
1	566	6	3	1	15	1613590.	13638.13638.13858.	45.	220.	48.	0.
1	566	14	0	1	8	1713598.	13642.13642.13786.	44.	144.	44.	0.
2	567	18	16	2	2	113626.	13881.13881.14362.	239.	482.	255.	0.
1	568	21	14	1	5	113653.	13667.13648.13865.	0.	198.	14.	19.
1	570	10	3	1	7	113690.	13693.13662.13840.	0.	147.	3.	31.
1	570	23	7	1	9	113703.	13710.13675.13855.	0.	145.	7.	35.
1	571	15	0	1	10	013719.	13719.13663.13910.	0.	191.	0.	56.
1	571	19	11	1	12	113723.	13734.13710.13863.	0.	129.	11.	24.
1	573	0	6	1	14	113752.	13758.13687.13865.	0.	107.	6.	71.
1	573	11	5	1	4	113763.	13768.13761.13927.	0.	159.	5.	7.
1	574	5	1	1	13	113781.	13785.13785.13961.	3.	177.	4.	0.
1	575	1	5	1	6	113801.	13806.13797.13975.	0.	169.	5.	9.

1	575	4	2	1	8	213804.	13806.	13786.	13907.	0.	101.	2.	20.
2	575	4	2	2	1	213804.	13883.	13883.	14290.	77.	406.	79.	0.
1	575	15	15	1	11	113815.	13830.	13808.	13927.	0.	97.	15.	22.
1	576	2	5	1	7	213826.	13840.	13840.	14120.	9.	280.	14.	0.
1	576	18	13	1	9	113842.	13855.	13855.	14000.	0.	145.	13.	0.
1	577	3	5	1	15	213851.	13858.	13858.	14075.	2.	217.	7.	0.
4	577	8	0	4	1	013856.	13856.	13423.	14005.	0.	149.	0.	433.
1	577	12	0	1	12	113860.	13863.	13863.	13953.	3.	90.	3.	0.
1	577	16	16	1	5	113864.	13880.	13865.	14000.	0.	120.	16.	15.
1	578	4	5	1	14	213876.	13881.	13865.	14074.	0.	193.	5.	16.
1	578	23	10	1	8	113895.	13907.	13907.	14097.	2.	190.	12.	0.
4	579	1	9	4	1	113897.	14005.	14005.	14146.	99.	141.	108.	0.
1	579	6	4	1	10	213902.	13910.	13910.	14075.	4.	164.	8.	0.
1	580	6	5	1	1	113926.	13931.	13912.	14196.	0.	265.	5.	19.
1	580	7	4	1	2	213927.	13931.	13929.	14100.	0.	169.	4.	2.
1	580	14	0	1	4	013934.	13934.	13927.	14100.	0.	166.	0.	7.
1	581	1	11	1	11	113945.	13956.	13927.	14124.	0.	168.	11.	29.
1	581	3	9	1	12	213947.	13956.	13953.	14053.	0.	97.	9.	3.
1	582	17	0	1	6	013985.	13985.	13975.	14167.	0.	182.	0.	10.
1	582	19	11	1	13	113987.	13998.	13961.	14153.	0.	155.	11.	37.
1	582	22	8	1	9	213990.	14000.	14000.	14173.	2.	173.	10.	0.
1	583	17	0	1	5	014009.	14009.	14000.	14142.	0.	133.	0.	9.
1	585	15	1	1	12	114055.	14056.	14053.	14240.	0.	184.	1.	3.
1	585	17	0	1	14	114057.	14074.	14074.	14238.	17.	164.	17.	0.
1	586	16	1	1	10	114080.	14081.	14075.	14249.	0.	168.	1.	6.
1	587	3	3	1	15	114091.	14094.	14075.	14244.	0.	150.	3.	19.
1	587	8	0	1	8	114096.	14097.	14097.	14267.	1.	170.	1.	0.
1	587	18	12	1	2	114106.	14118.	14100.	14263.	0.	145.	12.	18.
1	588	8	0	1	4	014120.	14120.	14100.	14315.	0.	195.	0.	20.
1	589	3	5	1	5	114139.	14144.	14142.	14315.	0.	171.	5.	2.
1	589	14	6	1	7	114150.	14156.	14120.	14312.	0.	156.	6.	36.
1	589	18	14	1	6	214154.	14168.	14167.	14348.	0.	180.	14.	1.
2	590	22	11	1	3	114182.	14193.	14178.	14721.	0.	528.	11.	15.
1	591	4	6	1	9	214188.	14194.	14173.	14362.	0.	168.	6.	21.
1	591	6	4	1	11	314190.	14194.	14124.	14388.	0.	194.	4.	70.
1	591	15	0	1	1	014199.	14199.	14196.	14363.	0.	164.	0.	3.
1	592	2	9	1	13	114210.	14219.	14153.	14387.	0.	168.	9.	66.
1	592	12	0	1	14	114220.	14238.	14238.	14411.	18.	173.	18.	0.
1	592	22	13	1	12	214230.	14243.	14240.	14366.	0.	123.	13.	3.
2	592	22	13	1	2	314230.	14263.	14263.	14604.	20.	341.	33.	0.
1	592	23	12	1	15	414231.	14244.	14244.	14399.	1.	155.	13.	0.
1	593	0	12	1	10	514232.	14249.	14249.	14345.	5.	95.	17.	0.
1	593	3	9	1	8	614235.	14267.	14267.	14412.	23.	145.	32.	0.
1	594	0	6	1	7	514256.	14312.	14312.	14440.	50.	127.	56.	0.
1	594	2	4	1	4	614258.	14315.	14315.	14455.	53.	140.	57.	0.
1	594	12	1	1	5	314268.	14315.	14315.	14455.	46.	140.	47.	0.
1	594	16	0	1	10	414272.	14345.	14345.	14461.	73.	117.	73.	0.
1	595	3	3	1	6	514283.	14348.	14348.	14479.	62.	131.	65.	0.
1	595	10	4	1	9	614290.	14362.	14362.	14526.	68.	164.	72.	0.
1	595	11	3	1	1	714291.	14363.	14363.	14551.	69.	188.	72.	0.
1	595	18	12	1	12	814298.	14366.	14366.	14502.	56.	136.	68.	0.
1	596	4	2	1	13	914308.	14387.	14387.	14488.	77.	100.	79.	0.
1	596	21	9	1	11	714325.	14388.	14388.	14552.	54.	163.	63.	0.
3	597	23	7	3	1	114351.	14358.	12343.	14551.	0.	193.	7.	2015.
2	598	2	4	2	1	114354.	14358.	14290.	14746.	0.	388.	4.	68.
1	598	20	10	1	15	314372.	14399.	14399.	14551.	17.	152.	27.	0.
1	599	18	12	1	14	214394.	14411.	14411.	14550.	5.	139.	17.	0.
1	600	5	2	1	8	214405.	14412.	14412.	14436.	5.	23.	7.	0.
1	601	0	8	1	8	114424.	14436.	14436.	14625.	4.	189.	12.	0.
1	601	10	0	1	7	214434.	14440.	14440.	14629.	6.	189.	6.	0.
1	602	6	3	1	4	114454.	14457.	14455.	14650.	0.	193.	3.	2.
1	602	7	2	1	5	214455.	14457.	14455.	14625.	0.	168.	2.	2.
1	603	3	7	1	6	114475.	14482.	14479.	14651.	0.	169.	7.	3.
1	604	8	3	1	10	114504.	14507.	14461.	14633.	0.	126.	3.	46.
4	605	11	1	4	1	114531.	14532.	14146.	14678.	0.	146.	1.	386.
1	606	10	3	1	1	114554.	14557.	14551.	[illegible]	0.	137.	3.	6.

1	606	13	0	1	9	014557.	14557.14526.14752.	0.	195.	0.	31.
1	607	18	12	1	11	114586.	14598.14552.14750.	0.	152.	12.	46.
1	607	23	7	1	12	214591.	14598.14502.14719.	0.	121.	7.	96.
2	608	0	6	2	2	114592.	14598.14362.15151.	0.	553.	6.	236.
1	608	12	3	1	2	114604.	14607.14604.14766.	0.	159.	3.	3.
1	609	2	4	1	13	114618.	14622.14488.14742.	0.	120.	4.	134.
2	609	3	3	1	1	214619.	14694.14694.15208.	72.	514.	75.	0.
4	609	13	3	4	1	114629.	14678.14678.14814.	46.	136.	49.	0.
1	610	12	5	1	4	214652.	14657.14650.14838.	0.	181.	5.	7.
4	611	14	4	4	1	114678.	14814.14814.15042.	132.	228.	136.	0.
1	612	14	5	1	5	114702.	14707.14625.14839.	0.	132.	5.	82.
1	613	6	2	1	6	114718.	14720.14651.14869.	0.	149.	2.	69.
4	613	13	0	4	1	214725.	15042.15042.15224.	317.	182.	317.	0.
1	614	15	6	1	3	114751.	14757.14721.14938.	0.	181.	6.	36.
1	614	22	11	1	2	114758.	14769.14766.14866.	0.	97.	11.	3.
1	615	3	7	1	7	214763.	14770.14629.14939.	0.	169.	7.	141.
1	615	6	4	1	8	314766.	14770.14625.14891.	0.	121.	4.	145.
1	615	23	11	1	9	114783.	14794.14752.14962.	0.	168.	11.	42.
1	616	7	4	1	10	214791.	14795.14633.15011.	0.	216.	4.	162.
1	617	5	7	1	11	114813.	14820.14750.14988.	0.	168.	7.	70.
1	617	5	7	1	12	214813.	14820.14719.15016.	0.	196.	7.	101.
1	617	12	0	1	13	014820.	14820.14742.15017.	0.	197.	0.	78.
1	617	20	16	1	4	114828.	14844.14838.14965.	0.	121.	16.	6.
1	618	8	5	1	5	214840.	14845.14839.14910.	0.	65.	5.	6.
1	619	6	0	1	14	014862.	14862.14550.15055.	0.	193.	0.	312.
2	620	10	5	2	1	114890.	14895.14746.15306.	0.	411.	5.	149.
1	621	23	7	1	2	114927.	14934.14866.15089.	0.	155.	7.	68.
1	622	11	6	1	3	114939.	14945.14938.15179.	0.	234.	6.	7.
2	622	11	6	1	2	214939.	15089.15089.15487.	144.	398.	150.	0.
1	623	12	18	1	4	214964.	14982.14965.15175.	0.	193.	18.	17.
1	623	19	11	1	5	314971.	14982.14910.15174.	0.	192.	11.	72.
1	624	9	0	1	6	414985.	14985.14869.15109.	0.	124.	0.	116.
1	624	16	15	1	7	514992.	15007.14939.15107.	0.	100.	15.	68.
4	625	14	18	4	1	215014.	15224.15224.15464.	192.	240.	210.	0.
1	627	0	10	1	8	615048.	15058.14891.15226.	0.	168.	10.	167.
1	627	4	6	1	9	715052.	15058.14962.15227.	0.	169.	6.	96.
1	627	9	1	1	10	815057.	15058.15011.15231.	0.	173.	1.	47.
1	628	5	6	1	11	915077.	15083.14988.15228.	0.	145.	6.	95.
1	629	0	12	1	7	115096.	15108.15107.15325.	0.	217.	12.	1.
1	629	11	1	1	12	215107.	15108.15016.15228.	0.	120.	1.	92.
1	629	18	18	1	6	115114.	15132.15109.15301.	0.	169.	18.	23.
1	630	1	5	1	13	215121.	15126.15017.15304.	0.	178.	5.	109.
1	631	23	7	1	14	115167.	15174.15055.15271.	0.	97.	7.	119.
1	632	8	0	1	4	015176.	15176.15175.15400.	0.	224.	0.	1.
1	632	17	0	1	3	015185.	15185.15179.15328.	0.	143.	0.	6.
4	633	11	5	4	1	215203.	15464.15464.15583.	256.	119.	261.	0.
1	634	5	1	1	1	115221.	15222.15208.15366.	0.	144.	1.	14.
1	634	6	0	1	5	015222.	15222.15174.15439.	0.	217.	0.	48.
1	634	9	0	1	15	015225.	15225.14551.15426.	0.	201.	0.	674.
1	636	22	9	1	8	115286.	15295.15226.15369.	0.	74.	9.	69.
1	638	9	0	1	6	015321.	15321.15301.15514.	0.	193.	0.	20.
2	638	22	11	2	1	115334.	15345.15306.15730.	0.	385.	11.	39.
1	639	14	0	1	3	015350.	15350.15328.15538.	0.	188.	0.	22.
4	640	16	0	4	1	215376.	15583.15583.15758.	207.	175.	207.	0.
1	641	5	7	1	1	115389.	15396.15366.15541.	0.	145.	7.	30.
1	641	20	16	1	4	115404.	15420.15400.15588.	0.	168.	16.	20.
1	642	2	4	1	7	215410.	15414.15325.15543.	0.	129.	4.	89.
1	642	7	6	1	8	315415.	15421.15369.15591.	0.	170.	6.	52.
1	642	16	0	1	9	015424.	15424.15227.15607.	0.	183.	0.	197.
1	643	2	4	1	10	115434.	15438.15231.15535.	0.	97.	4.	207.
2	643	4	2	2	2	115436.	15438.15151.15870.	0.	432.	2.	287.
2	643	12	2	1	2	115444.	15487.15487.15990.	41.	504.	43.	0.
1	643	23	7	1	5	215455.	15462.15439.15606.	0.	144.	7.	23.
1	644	4	2	1	11	315460.	15462.15228.15591.	0.	129.	2.	234.
1	645	2	4	1	12	415482.	15486.15228.15654.	0.	168.	4.	258.
4	[illegible]	5	1	4	1	[illegible]15509.	15758.15758.15919.	248.	141.	248.	0.

1	646	11	6	1	6	115515.	15521.15514.15737.	0.	216.	6.	7.
2	646	12	5	1	3	215516.	15538.15538.16098.	17.	559.	22.	0.
1	646	21	9	1	13	215525.	15534.15304.15726.	0.	192.	9.	230.
1	647	17	13	1	1	115545.	15558.15541.15702.	0.	144.	13.	17.
2	648	6	1	1	1	115558.	15702.15702.16327.	143.	625.	144.	0.
1	648	19	12	1	7	215571.	15583.15543.15776.	0.	193.	12.	40.
1	649	5	3	1	10	315581.	15584.15535.15704.	0.	120.	3.	49.
1	649	9	0	1	14	415585.	15585.15271.15752.	0.	167.	0.	314.
1	649	17	15	1	4	515593.	15608.15588.15776.	0.	168.	15.	20.
3	650	17	16	3	1	115617.	15633.14551.15969.	0.	336.	16.	1082.
1	651	6	4	1	5	615630.	15634.15606.15830.	0.	196.	4.	28.
1	651	8	2	1	8	715632.	15634.15591.15730.	0.	96.	2.	43.
1	652	14	0	1	9	815662.	15662.15607.15852.	0.	190.	0.	55.
1	652	23	12	1	11	915671.	15683.15591.15875.	0.	192.	12.	92.
1	653	7	5	1	12	1015679.	15684.15654.15903.	0.	219.	5.	30.
1	653	7	5	1	15	1115679.	15684.15426.15781.	0.	97.	5.	258.
4	653	14	0	4	1	215686.	15919.15919.16093.	233.	174.	233.	0.
1	655	15	0	1	8	015735.	15735.15730.15871.	0.	136.	0.	5.
1	656	21	9	1	6	115765.	15774.15737.16000.	0.	226.	9.	37.
2	657	3	3	2	1	115771.	15774.15730.16233.	.0.	459.	3.	44.
1	657	21	9	1	4	115789.	15798.15776.15977.	0.	179.	9.	22.
1	658	4	2	1	7	215796.	15798.15776.15846.	0.	48.	2.	22.
1	658	22	8	1	10	115814.	15822.15704.15945.	0.	123.	8.	118.
1	659	•2	4	1	13	215818.	15822.15726.15990.	0.	168.	4.	96.
1	659	14	4	1	5	115830.	15834.15830.16003.	0.	169.	4.	4.
2	660	9	0	2	2	115849.	15870.15870.16327.	21.	457.	21.	0.
1	660	10	0	1	7	015850.	15850.15846.15997.	0.	147.	0.	4.
1	660	20	11	1	8	115860.	15871.15871.16040.	0.	169.	11.	0.
1	661	0	8	1	9	215864.	15872.15852.16018.	0.	146.	8.	20.
1	661	1	7	1	14	315865.	15872.15752.16053.	0.	181.	7.	120.
1	661	13	0	1	11	015877.	15877.15875.16067.	0.	190.	0.	2.
1	661	23	9	1	15	115887.	15896.15781.16064.	0.	168.	9.	115.
1	662	21	12	1	12	115909.	15921.15903.16018.	0.	97.	12.	18.
1	665	16	0	1	10	015976.	15976.15945.16189.	0.	213.	0.	31.
4	666	9	4	4	1	115993.	16093.16093.16254.	96.	162.	100.	0.
2	666	17	0	1	2	016001.	16001.15990.16423.	0.	422.	0.	11.
2	667	7	0	1	3	116015.	16098.16098.16791.	83.	693.	83.	0.
1	668	1	5	1	4	216033.	16038.15977.16121.	0.	83.	5.	61.
3	668	10	5	3	1	116042.	16047.15969.16264.	0.	217.	5.	78.
2	668	20	10	2	1	116052.	16233.16233.16864.	171.	631.	181.	0.
1	669	0	6	1	5	316056.	16062.16003.16192.	0.	130.	6.	59.
1	669	13	3	1	6	416069.	16072.16000.16206.	0.	134.	3.	72.
2	670	10	0	2	2	216090.	16327.16327.17034.	237.	707.	237.	0.
2	671	12	18	1	1	116116.	16327.16327.16759.	193.	431.	211.	0.
4	671	17	13	4	1	116121.	16254.16254.16446.	120.	192.	133.	0.
1	673	8	0	1	4	216160.	16160.16121.16352.	0.	192.	0.	39.
2	673	15	17	1	2	316167.	16423.16423.16952.	239.	529.	256.	0.
2	674	20	13	1	1	416196.	16759.16759.17122.	550.	363.	563.	0.
1	675	17	17	1	5	516217.	16234.16192.16331.	0.	97.	17.	42.
1	676	3	8	1	6	616227.	16235.16206.16403.	0.	168.	8.	29.
1	676	20	15	1	7	716244.	16259.15997.16428.	0.	169.	15.	262.
1	677	3	9	1	8	816251.	16260.16040.16380.	0.	120.	9.	220.
1	680	10	5	1	5	716330.	16335.16331.16480.	0.	145.	5.	4.
1	680	19	11	1	9	816339.	16350.16018.16470.	0.	120.	11.	332.
2	682	16	1	1	3	916384.	16791.16791.17190.	406.	400.	407.	0.
1	684	7	0	1	4	916423.	16423.16352.16544.	0.	121.	0.	71.
1	685	5	3	1	6	1016445.	16448.16403.16605.	0.	157.	3.	45.
1	687	3	7	1	5	1116491.	16498.16480.16655.	0.	157.	7.	18.
2	688	16	0	2	1	116528.	16864.16864.17221.	336.	358.	336.	0.
1	689	18	18	1	4	1216554.	16572.16544.16718.	0.	146.	18.	28.
1	689	23	13	1	7	1316559.	16572.16428.16765.	0.	193.	13.	144.
2	690	20	10	1	2	1416580.	16952.16952.17297.	362.	345.	372.	0.
1	692	4	2	1	6	1516612.	16614.16605.16767.	0.	153.	2.	9.
1	692	4	2	1	8	1616612.	16614.16380.16791.	0.	177.	2.	234.
1	692	10	5	1	9	1716618.	16623.16470.16767.	0.	144.	5.	153.
1	692	17	0	1	10	1816625.	[illegible]	0.	[illegible]	0.	[illegible]

[illegible]										
1	693	8	0	1	11	1916640.	16640.16067.16830.	0.	190.	0. 573.
4	693	18	12	4	1	116650.	16662.16446.16807.	0.	145.	12. 216.
1	694	19	11	1	5	2016675.	16686.16655.16807.	0.	121.	11. 31.
1	695	12	18	1	12	2116692.	16710.16018.16903.	0.	193.	18. 692.
1	695	22	8	1	13	2216702.	16710.15990.16855.	0.	145.	8. 720.

FIRST 626. ARRIVALS IGNORED.

TYPE	AV.WT.	NO.ARRIV.	TOT.IDLETIME	%IDLE TIME	AV SERVICE	MAXQ
1.00	13.74	497.00	25706.67	301.30	160.34	50.00
2.00	235.26	84.00	931.12	10.91	453.79	4.00
3.00	29.07	10.00	5880.54	68.92	221.71	1.00
4.00	101.39	35.00	2757.45	32.32	161.63	2.00

TYPE=1 QUEUE LENGTHS

0	40
1	116
2	63
3	29
4	20
5	18
6	17
7	17
8	16
9	15
10	9
11	9
12	9
13	7
14	8
15	5
16	5
17	5
18	4
19	4
20	4
21	3
22	4
23	4
24	4
25	3
26	5
27	6
28	6
29	6
30	7
31	6
32	7
33	7
34	5
35	5
36	4
37	4
38	5
39	4
40	4
41	4
42	4
43	4
44	4
45	3
46	2
47	2
48	1
49	1
50	1

TYPE=2 QUEUE LENGTHS

0	1
1	21
2	9
3	3
4	2

TYPE=3 QUEUE LENGTHS

0	0
1	10

TYPE=4 QUEUE LENGTHS

0	3
1	24
2	8

TYPE=1 WAITING TIMES

0-11.99	336	12-23.99	83	24-35.99	23
36-47.99	11	48-59.99	16	60-71.99	10
72-83.99	9	84-95.99	4	96-107.99	3
108-119.99	2				

TYPE=2 WAITING TIMES

0-11.99	15	12-23.99	4		
24-35.99	1	36-47.99	1	48-59.99	1
60-71.99	2	72-83.99	6	84-95.99	1
108-119.99	1	120-131.99	2	144-155.99	2
156-167.99	4	168-179.99	1	180-191.99	1
192-203.99	1	204-215.99	4	216-227.99	2
228-239.99	2	240-251.99	1	252-263.99	2
276-287.99	2	288-299.99	1	324-335.99	2
348-359.99	1	360-371.99	2	372-383.99	1
384-395.99	1	396-407.99	2	408-419.99	1
432-443.99	1	444-455.99	3	504-515.99	1
528-539.99	2	540-551.99	2	552-563.99	1
564-575.99	1	576-587.99	1	600-611.99	5

TYPE=3 WAITING TIMES

0-11.99	6	12-23.99	3	204-215.99	1

TYPE=4 WAITING TIMES

0-11.99	11	12-23.99	1	36-47.99	2
48-59.99	1	60-71.99	1	72-83.99	1
84-95.99	1	96-107.99	3	108-119.99	3
132-143.99	3	204-215.99	2	228-239.99	1
240-251.99	2	252-263.99	1	312-323.99	1
348-359.99	1				

TYPE=1 IDLE TIMES

0-11.99	213	12-23.99	92	24-35.99	26
36-47.99	32	48-59.99	15	60-71.99	22
72-83.99	5	84-95.99	12	96-107.99	11
108-119.99	12	120-131.99	9	132-143.99	7
144-155.99	5	156-167.99	4	180-191.99	2
192-203.99	1	204-215.99	2	216-227.99	1
228-239.99	4	252-263.99	3	276-287.99	1
300-311.99	2	312-323.99	1	324-335.99	2
336-347.99	1	348-359.99	2	384-395.99	1
420-431.99	1	432-443.99	1	480-491.99	1
564-575.99	1	600-611.99	1	612-623.99	1
672-683.99	1	684-695.99	1	708-719.99	1

TYPE=2 IDLE TIMES

0-11.99	72	12-23.99	4	24-35.99	1
36-47.99	3	60-71.99	1	144-155.99	1
228-239.99	1	276-287.99	1		

TYPE=3 IDLE TIMES

0-11.99	1	72-83.99	1	216-227.99	1

252-263.99	1	324-335.99	1	444-455.99	2
984-995.99	1	1080-1091.99	1	1200-1211.99	1

TYPE=4 IDLE TIMES

0-11.99	24	12-23.99	1	60-71.99	1
84-95.99	2	204-215.99	1	216-227.99	1
348-359.99	1	372-383.99	1	384-395.99	1
432-443.99	1	480-491.99	1		

APPENDIX F

LISTING OF THE COMPUTER PROGRAMME AND SIMULATION OUTPUT FOR 1992 AND 1998

1992

```
>L.
    5 VDU 3
   10 R=RND(-1)
   20 ARRAYSZE=250:TIDE1=0: NEWDAYS=-1
   30 DIM SUMSERV(2),NUMB(2),STD(2),C(100,2),CI(200,2),Q(ARRAYSZE,2)
   40 DIM START(2),FA(2),QUEUE(2),MAXQL(2),CQ(250,2)
   50 DIM AVLOAD(2),AVUNLOAD(2),STIME(2),TCONST(2),NOBERTHS(2),BERTH(20,2)
   60 DIM TSERV(2),SUM(2),NO(2),SUMIT(2)
   70 @%=&01000004
   80 PRINT" TYP"," DAY"," HR"," TDE", " BTH"," BTH";" Q ";
   90 @%=&01000007
  100 PRINT  " ARRIV","ENTER","LEFT","LEAVE","DELAY","SERV","WAIT","IDLE"
  110 NOARRIVS=3836
  120 FDAYS=1919:NT=2:NN=1
  130 FOR T=1 TO NT:READ NOSHIPS:TCONST(T)=365*24/NOSHIPS
  140READ NOBERTHS(T),TSERV(T),STD(T):NEXTT
  150     REM***CALC.TIMEINTERVAL CONSTANT FOR EACH SHIP
  160 FOR T=1 TO NT:TCONST=TCONST(T):PROCINTERV
  170     REM***CALC TIME OF FIRST SHIP OF EACH TYPE.
  180 MAXQL(T)=0:QUEUE(T)=TRUE:START(T)=0: FA(T)=0
  190 STIME(T)=TINTERV:NEXT
  200    REM***FIND EARLIEST SHIP.
  210 GOTO220:FOR T=1 TO 3:STIME(T)=10^6:NO(T)=1:NUMB(T)=1 :NEXTT
  220 XSTIME=0:IDLET=0: STIME=10^6:FOR T=1 TO NT
  230IF STIME(T)<STIME THENSTIME=INT(STIME(T)):TYPE=T
  240 NEXT T:TPRINT=STIME
  250 HOURS=STIME MOD 24: DAYS=STIME DIV 24 :HRS=HOURS
  260 PROCDELAY(STIME)
  290 STIME=STIME+XSTIME
  300    REM*** CALC TIME TO LOAD & UNLOAD.
  310 PROCNORMAL
```

```
320 NOBERTH=NOBERTHS(TYPE):MINDELAY=100000
330 @%=&00000004
340 PRINT  TYPE,DAYS,HRS,XSTIME;
350 PROCMINDELAY
380 ENTERB=STIME+MINDELAY:PROCQSIZE :PRINT TYPE,FIRST,QL;
390 @%=&00020006:PRINT TPRINT,ENTERB,BERTH(FIRST,TYPE);
400 WAITIME=MINDELAY+XSTIME
410
420 BERTH(FIRST,TYPE)=STIME+MINDELAY+TSERVICE :HOURS=BERTH(FIRST,TYPE) MOD 24:
 LTIME=BERTH(FIRST,TYPE)
425 HR=HOURS
430 XSTIME=0: PROCDELAY(LTIME)
440 TSERVICE=TSERVICE+XSTIME: BERTH(FIRST,TYPE)=BERTH(FIRST,TYPE)+XSTIME
450 IF NN>FDAYS THEN SUMIT(TYPE)=SUMIT(TYPE)+IDLET:CQ(QL,TYPE)= CQ(QL,TYPE)+1
460 PRINT BERTH(FIRST,TYPE);"   ";
470 @%=&00020005:PRINT MINDELAY,TSERVICE,WAITIME,IDLET
490 IF NN<=FDAYS GOTO 530
500 SUM(TYPE)=SUM(TYPE)+WAITIME :NO(TYPE)=NO(TYPE)+1 : SUMSERV(TYPE)=SUMSERV(T
YPE)+TSERVICE:WT=INT(WAITIME/12):IF WT>50 THEN WT=50
510 IT=INT(IDLET/12):IF IT>100 THEN IT=100
520 C(WT,TYPE)=C(WT,TYPE)+1:CI(IT,TYPE)=CI(IT,TYPE)+1
530 TCONST=TCONST(TYPE)
540 IF NN=FDAYS THEN FDAYTIME=STIME
550 PROCINTERV
560 STIME(TYPE)=STIME(TYPE)+TINTERV
570 IF NN=NOARRIVS-10 THEN VDU2
580 NN=NN+1:IF NN<=NOARRIVS GOTO220
590PRINT' "FIRST ";FDAYS;" ARRIVALS IGNORED."
600 @%=&0002020B :TIMTOT=TPRINT-FDAYTIME
610 PRINT "          TYPE   AV.WT.     NO.ARRIV.   TOT.IDLETIME %IDLE TIME AV SE
RVICE  MAXQ"
620 FOR T=1 TO NT:PRINTT,SUM(T)/NO(T),NO(T),SUMIT(T),SUMIT(T)/TIMTOT*100,SUMSE
RV(T)/NO(T),MAXQL(T)
630 NEXT T
640 @%=&00000004
645 FOR T=1 TO NT :PRINT '"TYPE=";T;" QUEUE LENGTHS"
647 FOR IQ=0 TO MAXQL(T) :PRINT IQ,CQ(IQ,T)
648 NEXT IQ: NEXT T
650 FOR T=1 TO NT :PRINT'"TYPE=";T ;" WAITING TIMES"
660 FOR IW=0 TO 100
670 IF C(IW,T)<>0 PRINTIW*12;"-";IW*12+11.99,C(IW,T);"       ";:K=K+1:IF K MOD
3=0 PRINT
680 NEXT IW
690 NEXT T
700 FOR T=1 TO NT :PRINT'"TYPE=";T; " IDLE TIMES"
710 K=0:FOR IW=0 TO 200
720 IF CI(IW,T)<>0 PRINT IW*12;"-";IW*12+11.99,CI(IW,T);"       ";:K=K+1:IF K M
OD 3=0 THENPRINT
730 NEXT:NEXT  :PRINT
740 @%=10:VDU3:STOP
750 DEF PROCINTERV
760 R=RND(1)
770 TINTERV=-TCONST*LN(1-R)
780 ENDPROC
790 DEF PROCMINDELAY
810   REM***CHECK ALL BERTHS OF THIS TYPE.
820 FOR N=1 TO NOBERTH
840 DELAY=BERTH(N,TYPE)-STIME
850 IF DELAY<0 THEN MINDELAY=0 :FIRST=N :IDLET=-DELAY:GOTO870
860 IF DELAY<MINDELAY THEN MINDELAY=DELAY:FIRST=N
870 NEXT N
900 ENDPROC
940 DEF PROCNORMAL
950 SUMN=0:FOR I=1 TO 12:R=RND(1)
960 SUMN=SUMN+R:NEXT I
970 TSERVICE=STD(TYPE)*(SUMN-6.0)+TSERV(TYPE)
```

```
  980 ENDPROC
  990 DEF PROCQSIZE
 1000 START=START(TYPE):FA=FA(TYPE):QUEUE=QUEUE(TYPE)
 1010 Q(FA,TYPE)=ENTERB
 1020 QEND=FA
 1040 IF TPRINT<Q(START,TYPE) GOTO 1070
 1050 IF QUEUE AND START<QEND THEN START=START+1 :GOTO 1040
 1055 IF QUEUE AND START>=QEND THEN START=0 :  FA=0:QL=0:GOTO 1160
 1060 START=START+1
 1062 IF START>ARRAYSZE THEN START=0:QUEUE=TRUE
 1064 GOTO 1040
 1070 IF QUEUE THEN QL=QEND-START+1 ELSE QL=ARRAYSZE-START+QEND+2
 1080 FA=FA+1
 1090 IF FA>ARRAYSZE THEN FA=0:QUEUE=FALSE
 1110 IF QUEUE=FALSE AND FA>START THEN PRINT"Q TOO LONG";" START="START;" FA=";F
A ;" QL=";QL
 1160 START(TYPE)=START:FA(TYPE)=FA:QUEUE(TYPE)=QUEUE
 1170 IF NN>FDAYS AND QL>MAXQL(TYPE) THEN MAXQL(TYPE)=QL
 1180 ENDPROC
 1190 DATA 804,15,161,36
 1200 DATA 1115,7,54,9
 1490 DEF  PROCDELAY(LSTIME)
 1500 PROCXSTIME(0,6,HOURS):PROCXSTIME(18,30,HOURS)
 1510 D=DAYS-NEWDAYS :IF D=0 GOTO 1560
 1520 TIDE1=(TIDE1+D) MOD 24
 1530 TIDE2=(TIDE1+6) MOD 24
 1540 TIDE3=(TIDE1+12) MOD 24
 1550 TIDE4=(TIDE1+18) MOD 24
 1560 NEWDAYS=DAYS
 1570 IF TIDE2<TIDE1 THEN PROCXSTIME(0,TIDE2,HOURS): PROCXSTIME(TIDE1,TIDE2+24,H
OURS)ELSE PROCXSTIME(TIDE1,TIDE2,HOURS)
 1580 IF TIDE4<TIDE3 THEN PROCXSTIME(0,TIDE4,HOURS):PROCXSTIME(TIDE3,TIDE4+24,HO
URS) ELSE PROCXSTIME(TIDE3,TIDE4,HOURS)
 1590 IF XST<>0 GOTO 1500
 1600 ENDPROC
 1610  DEF PROCXSTIME(T1,T2,H)
 1620 XST=0
 1630 IF H>=T1 AND H<T2 THEN XST=T2-H :XSTIME=XSTIME+XST :HOURS=(LSTIME+XSTIME)
MOD 24
 1640 ENDPROC
>RUN
   2 736  11   0   2   3 12417675.  18752.18752.18828.  1077.      75.1077.   0.
   2 736  21  14   2   4 12517685.  18756.18756.18803.  1057.      48.1071.   0.
   2 737   5   7   2   2 12617693.  18757.18757.18805.  1057.      48.1064.   0.
   2 737   6   6   2   1 12717694.  18758.18758.18805.  1058.      47.1064.   0.
   2 737  12   0   2   5 12517700.  18764.18764.18829.  1064.      65.1064.   0.
   1 737  16   0   1  15  2817704.  18030.18030.18252.   326.     222. 326.   0.
   2 737  16   0   2   6 12617704.  18778.18778.18831.  1074.      53.1074.   0.
   2 737  17   0   2   7 12717705.  18803.18803.18858.  1098.      55.1098.   0.
   2 738   0   6   2   4 12817712.  18803.18803.18857.  1085.      53.1091.   0.
   1 738  18  12   1   9  2717730.  18041.18041.18205.   299.     165. 311.   0.

FIRST 1919. ARRIVALS IGNORED.
        TYPE    AV.WT.      NO.ARRIV.   TOT.IDLETIME %IDLE TIME AV SERVICE  MAXQ
        1.00     315.52      790.00        0.00        0.00      165.85      57.00
        2.00     729.25     1127.00        0.00        0.00       59.55     130.00

TYPE=1 QUEUE LENGTHS
   0   0
   1   0
   2   0
   3   0
   4   0
   5   0
   6   0
   7   0
```

8	0
9	0
10	1
11	6
12	5
13	8
14	13
15	19
16	31
17	29
18	31
19	36
20	26
21	32
22	45
23	46
24	56
25	31
26	20
27	13
28	13
29	20
30	10
31	11
32	9
33	8
34	9
35	18
36	24
37	16
38	26
39	14
40	14
41	13
42	9
43	11
44	14
45	10
46	12
47	16
48	9
49	5
50	9
51	10
52	12
53	8
54	3
55	3
56	4
57	2

TYPE=2 QUEUE LENGTHS

0	0
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0
11	0
12	0
13	0

14	0
15	0
16	0
17	0
18	0
19	0
20	0
21	0
22	0
23	0
24	0
25	0
26	0
27	0
28	0
29	0
30	0
31	0
32	0
33	0
34	0
35	0
36	0
37	0
38	0
39	0
40	0
41	0
42	1
43	1
44	2
45	2
46	2
47	2
48	4
49	7
50	16
51	14
52	13
53	8
54	11
55	17
56	21
57	21
58	17
59	16
60	22
61	21
62	27
63	37
64	33
65	28
66	29
67	11
68	11
69	13
70	22
71	20
72	25
73	25
74	27
75	22
76	16
77	19
78	17
79	11

80	12
81	12
82	6
83	7
84	10
85	7
86	4
87	2
88	3
89	7
90	9
91	11
92	9
93	9
94	3
95	2
96	4
97	5
98	4
99	3
100	3
101	4
102	4
103	3
104	4
105	3
106	1
107	3
108	5
109	7
110	10
111	8
112	11
113	12
114	17
115	20
116	18
117	18
118	17
119	14
120	15
121	23
122	26
123	26
124	24
125	23
126	26
127	22
128	13
129	4
130	3

TYPE=1 WAITING TIMES

84-95.99	1	96-107.99	3	108-119.99	2
120-131.99	3	132-143.99	17	144-155.99	19
156-167.99	19	168-179.99	38	180-191.99	38
192-203.99	31	204-215.99	27	216-227.99	43
228-239.99	51	240-251.99	42	252-263.99	35
264-275.99	25	276-287.99	28	288-299.99	30
300-311.99	13	312-323.99	12	324-335.99	12
336-347.99	15	348-359.99	10	360-371.99	25
372-383.99	20	384-395.99	20	396-407.99	17
408-419.99	14	420-431.99	27	432-443.99	9
444-455.99	5	456-467.99	18	468-479.99	12
480-491.99	5	492-503.99	17	504-515.99	11
516-527.99	8	528-539.99	3	540-551.99	4

```
 552-563.99   10        564-575.99      4        576-587.99       8
 588-599.99    8        600-611.99     31
TYPE=2 WAITING TIMES
 384-395.99    3
 396-407.99    6        408-419.99      5        420-431.99      26
 432-443.99   22        444-455.99     16        456-467.99      19
 468-479.99   34        480-491.99     33        492-503.99      28
 504-515.99   37        516-527.99     60        528-539.99      35
 540-551.99   36        552-563.99     21        564-575.99      16
 576-587.99   12        588-599.99     15        600-611.99     703

TYPE=1 IDLE TIMES
   0-11.99   790
TYPE=2 IDLE TIMES
   0-11.99  1127
>L.
    5 VDU 3
   10 R=RND(-1)
   20 ARRAYSZE=250:TIDE1=0: NEWDAYS=-1
   30 DIM SUMSERV(2),NUMB(2),STD(2),C(100,2),CI(200,2),Q(ARRAYSZE,2)
   40 DIM START(2),FA(2),QUEUE(2),MAXQL(2),CQ(250,2)
   50 DIM AVLOAD(2),AVUNLOAD(2),STIME(2),TCONST(2),NOBERTHS(2),BERTH(20,2)
   60 DIM TSERV(2),SUM(2),NO(2),SUMIT(2)
   70 @%=&01000004
   80 PRINT" TYP"," DAY"," HR"," TDE", " BTH"," BTH";" Q ";
   90 @%=&01000007
  100 PRINT  " ARRIV","ENTER","LEFT","LEAVE","DELAY","SERV","WAIT","IDLE"
  110 NOARRIVS=3836
  120 FDAYS=1919:NT=2:NN=1
  130 FOR T=1 TO NT:READ NOSHIPS:TCONST(T)=365*24/NOSHIPS
  140READ NOBERTHS(T),TSERV(T),STD(T):NEXTT
  150     REM***CALC.TIMEINTERVAL CONSTANT FOR EACH SHIP
  160 FOR T=1 TO NT:TCONST=TCONST(T):PROCINTERV
  170     REM***CALC TIME OF FIRST SHIP OF EACH TYPE.
  180 MAXQL(T)=0:QUEUE(T)=TRUE:START(T)=0: FA(T)=0
  190 STIME(T)=TINTERV:NEXT
  200   REM***FIND EARLIEST SHIP.
  210 GOTO220:FOR T=1 TO 3:STIME(T)=10^6:NO(T)=1:NUMB(T)=1 :NEXTT
  220 XSTIME=0:IDLET=0: STIME=10^6:FOR T=1 TO NT
  230IF STIME(T)<STIME THENSTIME=INT(STIME(T)):TYPE=T
  240 NEXT T:TPRINT=STIME
  250 HOURS=STIME MOD 24: DAYS=STIME DIV 24 :HRS=HOURS
  260 PROCDELAY(STIME)
  290 STIME=STIME+XSTIME
  300   REM*** CALC TIME TO LOAD & UNLOAD.
  310 PROCNORMAL
  320 NOBERTH=NOBERTHS(TYPE):MINDELAY=100000
  330 @%=&00000004
  340 PRINT  TYPE,DAYS,HRS,XSTIME;
  350 PROCMINDELAY
  380 ENTERB=STIME+MINDELAY:PROCQSIZE :PRINT TYPE,FIRST,QL;
  390 @%=&00020006:PRINT TPRINT,ENTERB,BERTH(FIRST,TYPE);
  400 WAITIME=MINDELAY+XSTIME
  410
  420 BERTH(FIRST,TYPE)=STIME+MINDELAY+TSERVICE :HOURS=BERTH(FIRST,TYPE) MOD 24:
 LTIME=BERTH(FIRST,TYPE)
  425 HR=HOURS
  430 XSTIME=0: PROCDELAY(LTIME)
  440 TSERVICE=TSERVICE+XSTIME: BERTH(FIRST,TYPE)=BERTH(FIRST,TYPE)+XSTIME
  450 IF NN>FDAYS THEN SUMIT(TYPE)=SUMIT(TYPE)+IDLET:CQ(QL,TYPE)= CQ(QL,TYPE)+1
  460 PRINT BERTH(FIRST,TYPE);"   ";
  470 @%=&00020005:PRINT MINDELAY,TSERVICE,WAITIME,IDLET
  490 IF NN<=FDAYS GOTO 530
  500 SUM(TYPE)=SUM(TYPE)+WAITIME :NO(TYPE)=NO(TYPE)+1 : SUMSERV(TYPE)=SUMSERV(T
YPE)+TSERVICE:WT=INT(WAITIME/12):IF WT>50 THEN WT=50
  510 IT=INT(IDLET/12):IF IT>100 THEN IT=100
```

```
520 C(WT,TYPE)=C(WT,TYPE)+1:CI(IT,TYPE)=CI(IT,TYPE)+1
530 TCONST=TCONST(TYPE)
540 IF NN=FDAYS THEN FDAYTIME=STIME
550 PROCINTERV
560 STIME(TYPE)=STIME(TYPE)+TINTERV
570 IF NN=NOARRIVS-10 THEN VDU2
580 NN=NN+1:IF NN<=NOARRIVS GOTO220
590PRINT' "FIRST ";FDAYS;" ARRIVALS IGNORED."
600 @%=&0002020B :TIMTOT=TPRINT-FDAYTIME
610 PRINT "          TYPE    AV.WT.      NO.ARRIV.   TOT.IDLETIME %IDLE TIME AV SE
RVICE  MAXQ"
620 FOR T=1 TO NT:PRINTT,SUM(T)/NO(T),NO(T),SUMIT(T),SUMIT(T)/TIMTOT*100,SUMSE
RV(T)/NO(T),MAXQL(T)
630 NEXT T
640 @%=&00000004
645 FOR T=1 TO NT :PRINT '"TYPE=";T:" QUEUE LENGTHS"
647 FOR IQ=0 TO MAXQL(T) :PRINT IQ,CQ(IQ,T)
648 NEXT IQ: NEXT T
650 FOR T=1 TO NT :PRINT'"TYPE=";T ;" WAITING TIMES"
660 FOR IW=0 TO 100
670 IF C(IW,T)<>0 PRINTIW*12;"-";IW*12+11.99,C(IW,T):"       ";:K=K+1:IF K MOD
3=0 PRINT
680 NEXT IW
690 NEXT T
700 FOR T=1 TO NT :PRINT'"TYPE=";T; " IDLE TIMES"
710 K=0:FOR IW=0 TO 200
720 IF CI(IW,T)<>0 PRINT IW*12;"-";IW*12+11.99,CI(IW,T);"       ";:K=K+1:IF K M
OD 3=0 THENPRINT
730 NEXT:NEXT  :PRINT
740 @%=10:VDU3:STOP
750 DEF PROCINTERV
760 R=RND(1)
770 TINTERV=-TCONST*LN(1-R)
780 ENDPROC
790 DEF PROCMINDELAY
810   REM***CHECK ALL BERTHS OF THIS TYPE.
820 FOR N=1 TO NOBERTH
840 DELAY=BERTH(N,TYPE)-STIME
850 IF DELAY<0 THEN MINDELAY=0 :FIRST=N :IDLET=-DELAY:GOTO870
860 IF DELAY<MINDELAY THEN MINDELAY=DELAY:FIRST=N
870 NEXT N
900 ENDPROC
940 DEF PROCNORMAL
950 SUMN=0:FOR I=1 TO 12:R=RND(1)
960 SUMN=SUMN+R:NEXT I
970 TSERVICE=STD(TYPE)*(SUMN-6.0)+TSERV(TYPE)
980 ENDPROC
990 DEF PROCQSIZE
1000 START=START(TYPE):FA=FA(TYPE):QUEUE=QUEUE(TYPE)
1010 Q(FA,TYPE)=ENTERB
1020 QEND=FA
1040 IF TPRINT<Q(START,TYPE) GOTO 1070
1050 IF QUEUE AND START<QEND THEN START=START+1 :GOTO 1040
1055 IF QUEUE AND START>=QEND THEN START=0 :  FA=0:QL=0:GOTO 1160
1060 START=START+1
1062 IF START>ARRAYSZE THEN START=0:QUEUE=TRUE
1064 GOTO 1040
1070 IF QUEUE THEN QL=QEND-START+1 ELSE QL=ARRAYSZE-START+QEND+2
1080 FA=FA+1
1090 IF FA>ARRAYSZE THEN FA=0:QUEUE=FALSE
1110 IF QUEUE=FALSE AND FA>START THEN PRINT"Q TOO LONG";" START="START;" FA=";F
A ;" QL=";QL
1160 START(TYPE)=START:FA(TYPE)=FA:QUEUE(TYPE)=QUEUE
1170 IF NN>FDAYS AND QL>MAXQL(TYPE) THEN MAXQL(TYPE)=QL
1180 ENDPROC
1190 DATA 804,16,161,36
```

```
 1200 DATA 1115,8,54,9
 1490 DEF  PROCDELAY(LSTIME)
 1500 PROCXSTIME(0,6,HOURS):PROCXSTIME(18,30,HOURS)
 1510 D=DAYS-NEWDAYS :IF D=0 GOTO 1560
 1520 TIDE1=(TIDE1+D) MOD 24
 1530 TIDE2=(TIDE1+6) MOD 24
 1540 TIDE3=(TIDE1+12) MOD 24
 1550 TIDE4=(TIDE1+18) MOD 24
 1560 NEWDAYS=DAYS
 1570 IF TIDE2<TIDE1 THEN PROCXSTIME(0,TIDE2,HOURS): PROCXSTIME(TIDE1,TIDE2+24,H
OURS)ELSE PROCXSTIME(TIDE1,TIDE2,HOURS)
 1580 IF TIDE4<TIDE3 THEN PROCXSTIME(0,TIDE4,HOURS):PROCXSTIME(TIDE3,TIDE4+24,HO
URS) ELSE PROCXSTIME(TIDE3,TIDE4,HOURS)
 1590 IF XST<>0 GOTO 1500
 1600 ENDPROC
 1610  DEF PROCXSTIME(T1,T2,H)
 1620 XST=0
 1630 IF H>=T1 AND H<T2 THEN XST=T2-H :XSTIME=XSTIME+XST :HOURS=(LSTIME+XSTIME)
MOD 24
 1640 ENDPROC
>RUN
   2 736  11   0   2   3   017675.  17675.17672.17747.    0.      72.   0.   3.
   2 736  21  14   2   8   117685.  17699.17697.17748.    0.      49.  14.   2.
   2 737   5   7   2   6   217693.  17700.17677.17749.    0.      49.   7.  23.
   2 737   6   6   2   5   317694.  17700.17700.17748.    0.      48.   6.   0.
   2 737  12   0   2   4   017700.  17700.17697.17754.    0.      54.   0.   3.
   1 737  16   0   1   7   717704.  17801.17801.18013.   97.     212.  97.   0.
   2 737  16   0   2   7   017704.  17704.17703.17772.    0.      68.   0.   1.
   2 737  17   0   2   1   017705.  17705.17647.17773.    0.      68.   0.  58.
   2 738   0   6   2   2   117712.  17725.17725.17790.    7.      65.  13.   0.
   1 738  18  12   1   9   817730.  17825.17825.17990.   83.     165.  95.   0.

FIRST 1919. ARRIVALS IGNORED.
        TYPE    AV.WT.      NO.ARRIV.   TOT.IDLETIME %IDLE TIME AV SERVICE  MAXQ
        1.00      50.91      790.00    10104.48      113.44      166.06      20.00
        2.00      37.29     1127.00     3899.49       43.78       59.52      20.00

TYPE=1 QUEUE LENGTHS
   0  59
   1 174
   2  99
   3  83
   4  62
   5  38
   6  33
   7  25
   8  17
   9  18
  10  22
  11  24
  12  24
  13  22
  14  15
  15  24
  16  25
  17  16
  18   5
  19   3
  20   2

TYPE=2 QUEUE LENGTHS
   0  55
   1 127
   2 130
   3 131
   4 121
```

```
  5 102
  6  88
  7  84
  8  79
  9  63
 10  34
 11  18
 12  11
 13   7
 14   5
 15   9
 16  14
 17  16
 18  15
 19  14
 20   4

TYPE=1 WAITING TIMES
   0-11.99    270        12-23.99 112        24-35.99  60
  36-47.99     56        48-59.99  47        60-71.99  25
  72-83.99     25        84-95.99  19        96-107.99      21
 108-119.99    16       120-131.99      23      132-143.99      34
 144-155.99    33       156-167.99      21      168-179.99      16
 180-191.99     6       192-203.99       1      204-215.99       3
 216-227.99     2
TYPE=2 WAITING TIMES
   0-11.99    274        12-23.99 202
  24-35.99    164        36-47.99 159        48-59.99 115
  60-71.99     75        72-83.99  40        84-95.99  22
  96-107.99    11       108-119.99      16      120-131.99      23
 132-143.99    21       144-155.99       5
TYPE=1 IDLE TIMES
   0-11.99    622        12-23.99  71        24-35.99  18
  36-47.99     29        48-59.99   7        60-71.99  10
  72-83.99      2        84-95.99   8        96-107.99       2
 108-119.99     1       120-131.99       5      132-143.99       2
 156-167.99     2       168-179.99       1      180-191.99       3
 276-287.99     2       300-311.99       1      324-335.99       1
 336-347.99     1       348-359.99       1      372-383.99       1

TYPE=2 IDLE TIMES
   0-11.99   1013        12-23.99  54        24-35.99  26
  36-47.99     11        48-59.99  11        60-71.99   4
  72-83.99      6        84-95.99   1       108-119.99       1

>L.
    5 VDU 3
   10 R=RND(-1)
   20 ARRAYSZE=250:TIDE1=0: NEWDAYS=-1
   30 DIM SUMSERV(2),NUMB(2),STD(2),C(100,2),CI(200,2),Q(ARRAYSZE,2)
   40 DIM START(2),FA(2),QUEUE(2),MAXQL(2),CQ(250,2)
   50 DIM AVLOAD(2),AVUNLOAD(2),STIME(2),TCONST(2),NOBERTHS(2),BERTH(20,2)
   60 DIM TSERV(2),SUM(2),NO(2),SUMIT(2)
   70 @%=&01000004
   80 PRINT" TYP"," DAY"," HR"," TDE", " BTH"," BTH";" Q ";
   90 @%=&01000007
  100 PRINT  " ARRIV","ENTER","LEFT","LEAVE","DELAY","SERV","WAIT","IDLE"
  110 NOARRIVS=3836
  120 FDAYS=1919:NT=2:NN=1
  130 FOR T=1 TO NT:READ NOSHIPS:TCONST(T)=365*24/NOSHIPS
  140READ NOBERTHS(T),TSERV(T),STD(T):NEXTT
  150     REM***CALC.TIMEINTERVAL CONSTANT FOR EACH SHIP
  160 FOR T=1 TO NT:TCONST=TCONST(T):PROCINTERV
  170     REM***CALC TIME OF FIRST SHIP OF EACH TYPE.
  180 MAXQL(T)=0:QUEUE(T)=TRUE:START(T)=0: FA(T)=0
  190 STIME(T)=TINTERV:NEXT
```

```
200   REM***FIND EARLIEST SHIP.
210 GOTO220:FOR T=1 TO 3:STIME(T)=10^6:NO(T)=1:NUMB(T)=1 :NEXTT
220 XSTIME=0:IDLET=0: STIME=10^6:FOR T=1 TO NT
230IF STIME(T)<STIME THENSTIME=INT(STIME(T)):TYPE=T
240 NEXT T:TPRINT=STIME
250 HOURS=STIME MOD 24: DAYS=STIME DIV 24 :HRS=HOURS
260 PROCDELAY(STIME)
290 STIME=STIME+XSTIME
300   REM*** CALC TIME TO LOAD & UNLOAD.
310 PROCNORMAL
320 NOBERTH=NOBERTHS(TYPE):MINDELAY=100000
330 @%=&00000004
340 PRINT  TYPE,DAYS,HRS,XSTIME;
350 PROCMINDELAY
380 ENTERB=STIME+MINDELAY:PROCQSIZE :PRINT TYPE,FIRST,QL;
390 @%=&00020006:PRINT TPRINT,ENTERB,BERTH(FIRST,TYPE);
400 WAITIME=MINDELAY+XSTIME
410
420 BERTH(FIRST,TYPE)=STIME+MINDELAY+TSERVICE :HOURS=BERTH(FIRST,TYPE) MOD 24:
 LTIME=BERTH(FIRST,TYPE)
425 HR=HOURS
430 XSTIME=0: PROCDELAY(LTIME)
440 TSERVICE=TSERVICE+XSTIME: BERTH(FIRST,TYPE)=BERTH(FIRST,TYPE)+XSTIME
450 IF NN>FDAYS THEN SUMIT(TYPE)=SUMIT(TYPE)+IDLET:CQ(QL,TYPE)= CQ(QL,TYPE)+1
460 PRINT BERTH(FIRST,TYPE);"  ";
470 @%=&00020005:PRINT MINDELAY,TSERVICE,WAITIME,IDLET
490 IF NN<=FDAYS GOTO 530
500 SUM(TYPE)=SUM(TYPE)+WAITIME :NO(TYPE)=NO(TYPE)+1 : SUMSERV(TYPE)=SUMSERV(T
YPE)+TSERVICE:WT=INT(WAITIME/12):IF WT>50 THEN WT=50
510 IT=INT(IDLET/12):IF IT>100 THEN IT=100
520 C(WT,TYPE)=C(WT,TYPE)+1:CI(IT,TYPE)=CI(IT,TYPE)+1
530 TCONST=TCONST(TYPE)
540 IF NN=FDAYS THEN FDAYTIME=STIME
550 PROCINTERV
560 STIME(TYPE)=STIME(TYPE)+TINTERV
570 IF NN=NOARRIVS-10 THEN VDU2
580 NN=NN+1:IF NN<=NOARRIVS GOTO220
590PRINT' "FIRST ";FDAYS;" ARRIVALS IGNORED."
600 @%=&0002020B :TIMTOT=TPRINT-FDAYTIME
610 PRINT "        TYPE   AV.WT.     NO.ARRIV.   TOT.IDLETIME %IDLE TIME AV SE
RVICE  MAXQ"
620 FOR T=1 TO NT:PRINTT,SUM(T)/NO(T),NO(T),SUMIT(T),SUMIT(T)/TIMTOT*100,SUMSE
RV(T)/NO(T),MAXQL(T)
630 NEXT T
640 @%=&00000004
645 FOR T=1 TO NT :PRINT '"TYPE=";T;" QUEUE LENGTHS"
647 FOR IQ=0 TO MAXQL(T) :PRINT IQ,CQ(IQ,T)
648 NEXT IQ: NEXT T
650 FOR T=1 TO NT :PRINT'"TYPE=";T ;" WAITING TIMES"
660 FOR IW=0 TO 100
670 IF C(IW,T)<>0 PRINTIW*12;"-";IW*12+11.99,C(IW,T);"      ";:K=K+1:IF K MOD
3=0 PRINT
680 NEXT IW
690 NEXT T
700 FOR T=1 TO NT :PRINT'"TYPE=";T; " IDLE TIMES"
710 K=0:FOR IW=0 TO 200
720 IF CI(IW,T)<>0 PRINT IW*12;"-";IW*12+11.99,CI(IW,T);"      ";:K=K+1:IF K M
OD 3=0 THENPRINT
730 NEXT:NEXT  :PRINT
740 @%=10:VDU3:STOP
750 DEF PROCINTERV
760 R=RND(1)
770 TINTERV=-TCONST*LN(1-R)
780 ENDPROC
790 DEF PROCMINDELAY
810   REM***CHECK ALL BERTHS OF THIS TYPE.
```

```
 820 FOR N=1 TO NOBERTH
 840 DELAY=BERTH(N,TYPE)-STIME
 850 IF DELAY<0 THEN MINDELAY=0 :FIRST=N :IDLET=-DELAY:GOTO870
 860 IF DELAY<MINDELAY THEN MINDELAY=DELAY:FIRST=N
 870 NEXT N
 900 ENDPROC
 940 DEF PROCNORMAL
 950 SUMN=0:FOR I=1 TO 12:R=RND(1)
 960 SUMN=SUMN+R:NEXT I
 970 TSERVICE=STD(TYPE)*(SUMN-6.0)+TSERV(TYPE)
 980 ENDPROC
 990 DEF PROCQSIZE
1000 START=START(TYPE):FA=FA(TYPE):QUEUE=QUEUE(TYPE)
1010 Q(FA,TYPE)=ENTERB
1020 QEND=FA
1040 IF TPRINT<Q(START,TYPE) GOTO 1070
1050 IF QUEUE AND START<QEND THEN START=START+1 :GOTO 1040
1055 IF QUEUE AND START>=QEND THEN START=0 :  FA=0:QL=0:GOTO 1160
1060 START=START+1
1062 IF START>ARRAYSZE THEN START=0:QUEUE=TRUE
1064 GOTO 1040
1070 IF QUEUE THEN QL=QEND-START+1 ELSE QL=ARRAYSZE-START+QEND+2
1080 FA=FA+1
1090 IF FA>ARRAYSZE THEN FA=0:QUEUE=FALSE
1110 IF QUEUE=FALSE AND FA>START THEN PRINT"Q TOO LONG";" START="START;" FA=";F
A ;" QL=";QL
1160 START(TYPE)=START:FA(TYPE)=FA:QUEUE(TYPE)=QUEUE
1170 IF NN>FDAYS AND QL>MAXQL(TYPE) THEN MAXQL(TYPE)=QL
1180 ENDPROC
1190 DATA 804,17,161,36
1200 DATA 1115,9,54,9
1490 DEF  PROCDELAY(LSTIME)
1500 PROCXSTIME(0,6,HOURS):PROCXSTIME(18,30,HOURS)
1510 D=DAYS-NEWDAYS :IF D=0 GOTO 1560
1520 TIDE1=(TIDE1+D) MOD 24
1530 TIDE2=(TIDE1+6) MOD 24
1540 TIDE3=(TIDE1+12) MOD 24
1550 TIDE4=(TIDE1+18) MOD 24
1560 NEWDAYS=DAYS
1570 IF TIDE2<TIDE1 THEN PROCXSTIME(0,TIDE2,HOURS): PROCXSTIME(TIDE1,TIDE2+24,H
OURS)ELSE PROCXSTIME(TIDE1,TIDE2,HOURS)
1580 IF TIDE4<TIDE3 THEN PROCXSTIME(0,TIDE4,HOURS):PROCXSTIME(TIDE3,TIDE4+24,HO
URS) ELSE PROCXSTIME(TIDE3,TIDE4,HOURS)
1590 IF XST<>0 GOTO 1500
1600 ENDPROC
1610  DEF PROCXSTIME(T1,T2,H)
1620 XST=0
1630 IF H>=T1 AND H<T2 THEN XST=T2-H :XSTIME=XSTIME+XST :HOURS=(LSTIME+XSTIME)
MOD 24
1640 ENDPROC
>RUN
   2 736  11   0   2   6   017675.   17675.17673.17747.     0.       72.   0.   2.
   2 736  21  14   2   9   117685.   17699.17684.17748.     0.       49.  14.  15.
   2 737   5   7   2   7   217693.   17700.17700.17749.     0.       49.   7.   0.
   2 737   6   6   2   5   317694.   17700.17672.17748.     0.       48.   6.  28.
   2 737  12   0   2   3   017700.   17700.17685.17754.     0.       54.   0.  15.
   1 737  16   0   1   5   517704.   17743.17743.17965.    39.      222.  39.   0.
   2 737  16   0   2   8   017704.   17704.17703.17772.     0.       68.   0.   1.
   2 737  17   0   2   2   017705.   17705.17647.17773.     0.       68.   0.  58.
   2 738   0   6   2   1   117712.   17718.17599.17773.     0.       55.   6. 119.
   1 738  18  12   1   2   317730.   17754.17754.17917.    12.      164.  24.   0.

FIRST 1919. ARRIVALS IGNORED.
        TYPE    AV.WT.      NO.ARRIV.   TOT.IDLETIME %IDLE TIME AV SERVICE  MAXQ
        1.00     28.60       790.00    19604.48      220.10      165.95      16.00
        2.00     14.32      1127.00    12749.78      143.14       59.61      12.00
```

```
TYPE=1 QUEUE LENGTHS
   0 113
   1 237
   2 124
   3  58
   4  35
   5  29
   6  25
   7  37
   8  31
   9  27
  10  28
  11  20
  12   8
  13   7
  14   6
  15   2
  16   3

TYPE=2 QUEUE LENGTHS
   0 126
   1 285
   2 241
   3 174
   4 110
   5  77
   6  47
   7  27
   8  15
   9  10
  10   7
  11   5
  12   3

TYPE=1 WAITING TIMES
   0-11.99    415          12-23.99 111         24-35.99  28
  36-47.99     28          48-59.99  49         60-71.99  33
  72-83.99     31          84-95.99  33         96-107.99      34
 108-119.99    13         120-131.99       6       132-143.99       5
 144-155.99     2         156-167.99       1       168-179.99       1

TYPE=2 WAITING TIMES
   0-11.99    595          12-23.99 326         24-35.99  98
  36-47.99     71          48-59.99  24         60-71.99  12
  72-83.99      1
TYPE=1 IDLE TIMES
   0-11.99    496          12-23.99 111         24-35.99  40
  36-47.99     48          48-59.99  16         60-71.99  12
  72-83.99      9          84-95.99   9         96-107.99       4
 108-119.99     4         120-131.99       7       132-143.99       7
 144-155.99     2         156-167.99       4       168-179.99       2
 180-191.99     2         192-203.99       2       204-215.99       1
 216-227.99     2         252-263.99       3       276-287.99       1
 288-299.99     1         348-359.99       1       372-383.99       1
 396-407.99     1         444-455.99       1       504-515.99       1
 684-695.99     1         876-887.99       1
TYPE=2 IDLE TIMES
   0-11.99    805          12-23.99 149         24-35.99  62
  36-47.99     29          48-59.99  26         60-71.99  17
  72-83.99      9          84-95.99   9         96-107.99       5
 108-119.99     8         120-131.99       2       132-143.99       2
 144-155.99     3         180-191.99       1
>L.
    5 VDU 3
   10 R=RND(-1)
```

```
 20 ARRAYSZE=250:TIDE1=0: NEWDAYS=-1
 30 DIM SUMSERV(2),NUMB(2),STD(2),C(100,2),CI(200,2),Q(ARRAYSZE,2)
 40 DIM START(2),FA(2),QUEUE(2),MAXQL(2),CQ(250,2)
 50 DIM AVLOAD(2),AVUNLOAD(2),STIME(2),TCONST(2),NOBERTHS(2),BERTH(20,2)
 60 DIM TSERV(2),SUM(2),NO(2),SUMIT(2)
 70 @%=&01000004
 80 PRINT" TYP"," DAY"," HR"," TDE", " BTH"," BTH";" Q ";
 90 @%=&01000007
100 PRINT  " ARRIV","ENTER","LEFT","LEAVE","DELAY","SERV","WAIT","IDLE"
110 NOARRIVS=3836
120 FDAYS=1919:NT=2:NN=1
130 FOR T=1 TO NT:READ NOSHIPS:TCONST(T)=365*24/NOSHIPS
140READ NOBERTHS(T),TSERV(T),STD(T):NEXTT
150    REM***CALC.TIMEINTERVAL CONSTANT FOR EACH SHIP
160 FOR T=1 TO NT:TCONST=TCONST(T):PROCINTERV
170    REM***CALC TIME OF FIRST SHIP OF EACH TYPE.
180 MAXQL(T)=0:QUEUE(T)=TRUE:START(T)=0: FA(T)=0
190 STIME(T)=TINTERV:NEXT
200   REM***FIND EARLIEST SHIP.
210 GOTO220:FOR T=1 TO 3:STIME(T)=10^6:NO(T)=1:NUMB(T)=1 :NEXTT
220 XSTIME=0:IDLET=0: STIME=10^6:FOR T=1 TO NT
230IF STIME(T)<STIME THENSTIME=INT(STIME(T)):TYPE=T
240 NEXT T:TPRINT=STIME
250 HOURS=STIME MOD 24: DAYS=STIME DIV 24 :HRS=HOURS
260 PROCDELAY(STIME)
290 STIME=STIME+XSTIME
300   REM*** CALC TIME TO LOAD & UNLOAD.
310 PROCNORMAL
320 NOBERTH=NOBERTHS(TYPE):MINDELAY=100000
330 @%=&00000004
340 PRINT  TYPE,DAYS,HRS,XSTIME;
350 PROCMINDELAY
380 ENTERB=STIME+MINDELAY:PROCQSIZE :PRINT TYPE,FIRST,QL;
390 @%=&00020006:PRINT TPRINT,ENTERB,BERTH(FIRST,TYPE);
400 WAITIME=MINDELAY+XSTIME
410
420 BERTH(FIRST,TYPE)=STIME+MINDELAY+TSERVICE :HOURS=BERTH(FIRST,TYPE) MOD 24:
 LTIME=BERTH(FIRST,TYPE)
425 HR=HOURS
430 XSTIME=0: PROCDELAY(LTIME)
440 TSERVICE=TSERVICE+XSTIME: BERTH(FIRST,TYPE)=BERTH(FIRST,TYPE)+XSTIME
450 IF NN>FDAYS THEN SUMIT(TYPE)=SUMIT(TYPE)+IDLET:CQ(QL,TYPE)= CQ(QL,TYPE)+1
460 PRINT BERTH(FIRST,TYPE);"  ";
470 @%=&00020005:PRINT MINDELAY,TSERVICE,WAITIME,IDLET
490 IF NN<=FDAYS GOTO 530
500 SUM(TYPE)=SUM(TYPE)+WAITIME :NO(TYPE)=NO(TYPE)+1 : SUMSERV(TYPE)=SUMSERV(T
YPE)+TSERVICE:WT=INT(WAITIME/12):IF WT>50 THEN WT=50
510 IT=INT(IDLET/12):IF IT>100 THEN IT=100
520 C(WT,TYPE)=C(WT,TYPE)+1:CI(IT,TYPE)=CI(IT,TYPE)+1
530 TCONST=TCONST(TYPE)
540 IF NN=FDAYS THEN FDAYTIME=STIME
550 PROCINTERV
560 STIME(TYPE)=STIME(TYPE)+TINTERV
570 IF NN=NOARRIVS-10 THEN VDU2
580 NN=NN+1:IF NN<=NOARRIVS GOTO220
590PRINT' "FIRST ";FDAYS;" ARRIVALS IGNORED."
600 @%=&0002020B :TIMTOT=TPRINT-FDAYTIME
610 PRINT "         TYPE    AV.WT.     NO.ARRIV.   TOT.IDLETIME %IDLE TIME AV SE
RVICE  MAXQ"
620 FOR T=1 TO NT:PRINTT,SUM(T)/NO(T),NO(T),SUMIT(T),SUMIT(T)/TIMTOT*100,SUMSE
RV(T)/NO(T),MAXQL(T)
630 NEXT T
640 @%=&00000004
645 FOR T=1 TO NT :PRINT '"TYPE=";T;" QUEUE LENGTHS"
647 FOR IQ=0 TO MAXQL(T) :PRINT IQ,CQ(IQ,T)
648 NEXT IQ: NEXT T
```

```
 650 FOR T=1 TO NT :PRINT'"TYPE=";T ;" WAITING TIMES"
 660 FOR IW=0 TO 100
 670 IF C(IW,T)<>0 PRINTIW*12;"-";IW*12+11.99,C(IW,T);"          ";:K=K+1:IF K MOD
3=0 PRINT
 680 NEXT IW
 690 NEXT T
 700 FOR T=1 TO NT :PRINT'"TYPE=";T; " IDLE TIMES"
 710 K=0:FOR IW=0 TO 200
 720 IF CI(IW,T)<>0 PRINT IW*12;"-";IW*12+11.99,CI(IW,T);"          ";:K=K+1:IF K M
OD 3=0 THENPRINT
 730 NEXT:NEXT  :PRINT
 740 @%=10:VDU3:STOP
 750 DEF PROCINTERV
 760 R=RND(1)
 770 TINTERV=-TCONST*LN(1-R)
 780 ENDPROC
 790 DEF PROCMINDELAY
 810   REM***CHECK ALL BERTHS OF THIS TYPE.
 820 FOR N=1 TO NOBERTH
 840 DELAY=BERTH(N,TYPE)-STIME
 850 IF DELAY<0 THEN MINDELAY=0 :FIRST=N :IDLET=-DELAY:GOTO870
 860 IF DELAY<MINDELAY THEN MINDELAY=DELAY:FIRST=N
 870 NEXT N
 900 ENDPROC
 940 DEF PROCNORMAL
 950 SUMN=0:FOR I=1 TO 12:R=RND(1)
 960 SUMN=SUMN+R:NEXT I
 970 TSERVICE=STD(TYPE)*(SUMN-6.0)+TSERV(TYPE)
 980 ENDPROC
 990 DEF PROCQSIZE
1000 START=START(TYPE):FA=FA(TYPE):QUEUE=QUEUE(TYPE)
1010 Q(FA,TYPE)=ENTERB
1020 QEND=FA
1040 IF TPRINT<Q(START,TYPE) GOTO 1070
1050 IF QUEUE AND START<QEND THEN START=START+1 :GOTO 1040
1055 IF QUEUE AND START>=QEND THEN START=0 :  FA=0:QL=0:GOTO 1160
1060 START=START+1
1062 IF START>ARRAYSZE THEN START=0:QUEUE=TRUE
1064 GOTO 1040
1070 IF QUEUE THEN QL=QEND-START+1 ELSE QL=ARRAYSZE-START+QEND+2
1080 FA=FA+1
1090 IF FA>ARRAYSZE THEN FA=0:QUEUE=FALSE
1110 IF QUEUE=FALSE AND FA>START THEN PRINT"Q TOO LONG";" START="START;" FA=";F
A ;" QL=";QL
1160 START(TYPE)=START:FA(TYPE)=FA:QUEUE(TYPE)=QUEUE
1170 IF NN>FDAYS AND QL>MAXQL(TYPE) THEN MAXQL(TYPE)=QL
1180 ENDPROC
1190 DATA 804,18,161,36
1200 DATA 1115,10,54,9
1490 DEF  PROCDELAY(LSTIME)
1500 PROCXSTIME(0,6,HOURS):PROCXSTIME(18,30,HOURS)
1510 D=DAYS-NEWDAYS :IF D=0 GOTO 1560
1520 TIDE1=(TIDE1+D) MOD 24
1530 TIDE2=(TIDE1+6) MOD 24
1540 TIDE3=(TIDE1+12) MOD 24
1550 TIDE4=(TIDE1+18) MOD 24
1560 NEWDAYS=DAYS
1570 IF TIDE2<TIDE1 THEN PROCXSTIME(0,TIDE2,HOURS): PROCXSTIME(TIDE1,TIDE2+24,H
OURS)ELSE PROCXSTIME(TIDE1,TIDE2,HOURS)
1580 IF TIDE4<TIDE3 THEN PROCXSTIME(0,TIDE4,HOURS):PROCXSTIME(TIDE3,TIDE4+24,HO
URS) ELSE PROCXSTIME(TIDE3,TIDE4,HOURS)
1590 IF XST<>0 GOTO 1500
1600 ENDPROC
1610  DEF PROCXSTIME(T1,T2,H)
1620 XST=0
1630 IF H>=T1 AND H<T2 THEN XST=T2-H :XSTIME=XSTIME+XST :HOURS=(LSTIME+XSTIME)
```

```
MOD 24
 1640 ENDPROC
>RUN
   2 736  11   0   2   8   017675.  17675.17673.17747.     0.     72.   0.   2.
   2 736  21  14   2   9   117685.  17699.17684.17748.     0.     49.  14.  15.
   2 737   5   7   2  10   217693.  17700.17700.17749.     0.     49.   7.   0.
   2 737   6   6   2   5   317694.  17700.17672.17748.     0.     48.   6.  28.
   2 737  12   0   2   4   017700.  17700.17685.17754.     0.     54.   0.  15.
   1 737  16   0   1  16   017704.  17704.17696.17917.     0.    213.   0.   8.
   2 737  16   0   2   7   017704.  17704.17703.17772.     0.     68.   0.   1.
   2 737  17   0   2   3   017705.  17705.17599.17773.     0.     68.   0. 106.
   2 738   0   6   2   2   117712.  17718.17599.17773.     0.     55.   6. 119.
   1 738  18  12   1   8   117730.  17742.17730.17911.     0.    169.  12.  12.

FIRST 1919. ARRIVALS IGNORED.
       TYPE    AV.WT.     NO.ARRIV.   TOT.IDLETIME %IDLE TIME AV SERVICE  MAXQ
       1.00     18.46      790.00    29074.45      326.42      165.96      15.00
       2.00      8.64     1127.00    21583.21      242.32       59.64       8.00

TYPE=1 QUEUE LENGTHS
   0 145
   1 276
   2 135
   3  54
   4  36
   5  23
   6  30
   7  25
   8  22
   9  18
  10   8
  11   6
  12   5
  13   5
  14   1
  15   1

TYPE=2 QUEUE LENGTHS
   0 192
   1 364
   2 254
   3 159
   4  88
   5  44
   6  16
   7   9
   8   1

TYPE=1 WAITING TIMES
   0-11.99    502        12-23.99 103        24-35.99  29
  36-47.99     37        48-59.99  38        60-71.99  30
  72-83.99     28        84-95.99  11        96-107.99      3
 108-119.99     5      120-131.99       3       132-143.99       1

TYPE=2 WAITING TIMES
   0-11.99    794        12-23.99 269        24-35.99  49
  36-47.99     15
TYPE=1 IDLE TIMES
   0-11.99    424        12-23.99 128        24-35.99  47
  36-47.99     56        48-59.99  16        60-71.99  18
  72-83.99      9        84-95.99  15        96-107.99      7
 108-119.99    12      120-131.99       8       132-143.99      10
 144-155.99     5      156-167.99       1       168-179.99       2
 180-191.99     2      192-203.99       2       204-215.99       2
 216-227.99     1      228-239.99       2       252-263.99       5
 276-287.99     1      288-299.99       1       300-311.99       1
```

```
 312-323.99     2        348-357.99       2        360-371.99       1
 372-383.99     3        396-407.99       1        612-623.99       1
 624-635.99     1        648-659.99       1        816-827.99       1
 948-959.99     1       1200-1211.99      1
TYPE=2 IDLE TIMES
   0-11.99    649         12-23.99 212          24-35.99  80
  36-47.99     49         48-59.99  33          60-71.99  18
  72-83.99     25         84-95.99  19          96-107.99      9
 108-119.99     7        120-131.99       6        132-143.99       2
 144-155.99     6        156-167.99       4        168-179.99       1
 180-191.99     2        204-215.99       4        408-419.99       1

>L.
    5 VDU 3
   10 R=RND(-1)
   20 ARRAYSZE=250:TIDE1=0: NEWDAYS=-1
   30 DIM SUMSERV(2),NUMB(2),STD(2),C(100,2),CI(200,2),Q(ARRAYSZE,2)
   40 DIM START(2),FA(2),QUEUE(2),MAXQL(2),CQ(250,2)
   50 DIM AVLOAD(2),AVUNLOAD(2),STIME(2),TCONST(2),NOBERTHS(2),BERTH(20,2)
   60 DIM TSERV(2),SUM(2),NO(2),SUMIT(2)
   70 @%=&01000004
   80 PRINT" TYP"," DAY"," HR"," TDE", " BTH"," BTH":" D ";
   90 @%=&01000007
  100 PRINT  " ARRIV","ENTER","LEFT","LEAVE","DELAY","SERV","WAIT","IDLE"
  110 NOARRIVS=3836
  120 FDAYS=1919:NT=2:NN=1
  130 FOR T=1 TO NT:READ NOSHIPS:TCONST(T)=365*24/NOSHIPS
  140READ NOBERTHS(T),TSERV(T),STD(T):NEXTT
  150    REM***CALC.TIMEINTERVAL CONSTANT FOR EACH SHIP
  160 FOR T=1 TO NT:TCONST=TCONST(T):PROCINTERV
  170    REM***CALC TIME OF FIRST SHIP OF EACH TYPE.
  180 MAXQL(T)=0:QUEUE(T)=TRUE:START(T)=0: FA(T)=0
  190 STIME(T)=TINTERV:NEXT
  200   REM***FIND EARLIEST SHIP.
  210 GOTO220:FOR T=1 TO 3:STIME(T)=10^6:NO(T)=1:NUMB(T)=1 :NEXTT
  220 XSTIME=0:IDLET=0: STIME=10^6:FOR T=1 TO NT
  230IF STIME(T)<STIME THENSTIME=INT(STIME(T)):TYPE=T
  240 NEXT T:TPRINT=STIME
  250 HOURS=STIME MOD 24: DAYS=STIME DIV 24 :HRS=HOURS
  260 PROCDELAY(STIME)
  290 STIME=STIME+XSTIME
  300   REM*** CALC TIME TO LOAD & UNLOAD.
  310 PROCNORMAL
  320 NOBERTH=NOBERTHS(TYPE):MINDELAY=100000
  330 @%=&00000004
  340 PRINT  TYPE,DAYS,HRS,XSTIME;
  350 PROCMINDELAY
  380 ENTERB=STIME+MINDELAY:PROCQSIZE :PRINT TYPE,FIRST,QL;
  390 @%=&00020006:PRINT TPRINT,ENTERB,BERTH(FIRST,TYPE);
  400 WAITIME=MINDELAY+XSTIME
  410
  420 BERTH(FIRST,TYPE)=STIME+MINDELAY+TSERVICE :HOURS=BERTH(FIRST,TYPE) MOD 24:
 LTIME=BERTH(FIRST,TYPE)
  425 HR=HOURS
  430 XSTIME=0: PROCDELAY(LTIME)
  440 TSERVICE=TSERVICE+XSTIME: BERTH(FIRST,TYPE)=BERTH(FIRST,TYPE)+XSTIME
  450 IF NN>FDAYS THEN SUMIT(TYPE)=SUMIT(TYPE)+IDLET:CQ(QL,TYPE)= CQ(QL,TYPE)+1
  460 PRINT BERTH(FIRST,TYPE);"   ";
  470 @%=&00020005:PRINT MINDELAY,TSERVICE,WAITIME,IDLET
  490 IF NN<=FDAYS GOTO 530
  500 SUM(TYPE)=SUM(TYPE)+WAITIME :NO(TYPE)=NO(TYPE)+1 : SUMSERV(TYPE)=SUMSERV(T
YPE)+TSERVICE:WT=INT(WAITIME/12):IF WT>50 THEN WT=50
  510 IT=INT(IDLET/12):IF IT>100 THEN IT=100
  520 C(WT,TYPE)=C(WT,TYPE)+1:CI(IT,TYPE)=CI(IT,TYPE)+1
  530 TCONST=TCONST(TYPE)
  540 IF NN=FDAYS THEN FDAYTIME=STIME
```

```
  550 PROCINTERV
  560 STIME(TYPE)=STIME(TYPE)+TINTERV
  570 IF NN=NOARRIVS-10 THEN VDU2
  580 NN=NN+1:IF NN<=NOARRIVS GOTO220
  590PRINT' "FIRST ";FDAYS;" ARRIVALS IGNORED."
  600 @%=&0002020B :TIMTOT=TPRINT-FDAYTIME
  610 PRINT "          TYPE    AV.WT.      NO.ARRIV.    TOT.IDLETIME %IDLE TIME AV SE
RVICE  MAXQ"
  620 FOR T=1 TO NT:PRINTT,SUM(T)/NO(T),NO(T),SUMIT(T),SUMIT(T)/TIMTOT*100,SUMSE
RV(T)/NO(T),MAXQL(T)
  630 NEXT T
  640 @%=&00000004
  645 FOR T=1 TO NT :PRINT '"TYPE=";T;" QUEUE LENGTHS"
  647 FOR IQ=0 TO MAXQL(T) :PRINT IQ,CQ(IQ,T)
  648 NEXT IQ: NEXT T
  650 FOR T=1 TO NT :PRINT'"TYPE=";T ;" WAITING TIMES"
  660 FOR IW=0 TO 100
  670 IF C(IW,T)<>0 PRINTIW*12;"-";IW*12+11.99,C(IW,T);"         ";:K=K+1:IF K MOD
3=0 PRINT
  680 NEXT IW
  690 NEXT T
  700 FOR T=1 TO NT :PRINT'"TYPE=";T; " IDLE TIMES"
  710 K=0:FOR IW=0 TO 200
  720 IF CI(IW,T)<>0 PRINT IW*12;"-";IW*12+11.99,CI(IW,T);"         ";:K=K+1:IF K M
OD 3=0 THENPRINT
  730 NEXT:NEXT  :PRINT
  740 @%=10:VDU3:STOP
  750 DEF PROCINTERV
  760 R=RND(1)
  770 TINTERV=-TCONST*LN(1-R)
  780 ENDPROC
  790 DEF PROCMINDELAY
  810   REM***CHECK ALL BERTHS OF THIS TYPE.
  820 FOR N=1 TO NOBERTH
  840 DELAY=BERTH(N,TYPE)-STIME
  850 IF DELAY<0 THEN MINDELAY=0 :FIRST=N :IDLET=-DELAY:GOTO870
  860 IF DELAY<MINDELAY THEN MINDELAY=DELAY:FIRST=N
  870 NEXT N
  900 ENDPROC
  940 DEF PROCNORMAL
  950 SUMN=0:FOR I=1 TO 12:R=RND(1)
  960 SUMN=SUMN+R:NEXT I
  970 TSERVICE=STD(TYPE)*(SUMN-6.0)+TSERV(TYPE)
  980 ENDPROC
  990 DEF PROCQSIZE
 1000 START=START(TYPE):FA=FA(TYPE):QUEUE=QUEUE(TYPE)
 1010 Q(FA,TYPE)=ENTERB
 1020 QEND=FA
 1040 IF TPRINT<Q(START,TYPE) GOTO 1070
 1050 IF QUEUE AND START<QEND THEN START=START+1 :GOTO 1040
 1055 IF QUEUE AND START>=QEND THEN START=0 :  FA=0:QL=0:GOTO 1160
 1060 START=START+1
 1062 IF START>ARRAYSZE THEN START=0:QUEUE=TRUE
 1064 GOTO 1040
 1070 IF QUEUE THEN QL=QEND-START+1 ELSE QL=ARRAYSZE-START+QEND+2
 1080 FA=FA+1
 1090 IF FA>ARRAYSZE THEN FA=0:QUEUE=FALSE
 1110 IF QUEUE=FALSE AND FA>START THEN PRINT"Q TOO LONG";" START="START;" FA=";F
A ;" QL=";QL
 1160 START(TYPE)=START:FA(TYPE)=FA:QUEUE(TYPE)=QUEUE
 1170 IF NN>FDAYS AND QL>MAXQL(TYPE) THEN MAXQL(TYPE)=QL
 1180 ENDPROC
 1190 DATA 804,19,161,36
 1200 DATA 1115,11,54,9
 1490 DEF  PROCDELAY(LSTIME)
 1500 PROCXSTIME(0,6,HOURS):PROCXSTIME(18,30,HOURS)
```

```
 1510 D=DAYS-NEWDAYS :IF D=0 GOTO 1560
 1520 TIDE1=(TIDE1+D) MOD 24
 1530 TIDE2=(TIDE1+6) MOD 24
 1540 TIDE3=(TIDE1+12) MOD 24
 1550 TIDE4=(TIDE1+18) MOD 24
 1560 NEWDAYS=DAYS
 1570 IF TIDE2<TIDE1 THEN PROCXSTIME(0,TIDE2,HOURS): PROCXSTIME(TIDE1,TIDE2+24,H
OURS)ELSE PROCXSTIME(TIDE1,TIDE2,HOURS)
 1580 IF TIDE4<TIDE3 THEN PROCXSTIME(0,TIDE4,HOURS):PROCXSTIME(TIDE3,TIDE4+24,HO
URS) ELSE PROCXSTIME(TIDE3,TIDE4,HOURS)
 1590 IF XST<>0 GOTO 1500
 1600 ENDPROC
 1610  DEF PROCXSTIME(T1,T2,H)
 1620 XST=0
 1630 IF H>=T1 AND H<T2 THEN XST=T2-H :XSTIME=XSTIME+XST :HOURS=(LSTIME+XSTIME)
MOD 24
 1640 ENDPROC
>RUN
   2 736  11   0   2  10   017675.  17675.17672.17747.    0.      72.   0.    3.
   2 736  21  14   2   9   117685.  17699.17684.17748.    0.      49.  14.   15.
   2 737   5   7   2   8   217693.  17700.17673.17749.    0.      49.   7.   27.
   2 737   6   6   2   7   317694.  17700.17700.17748.    0.      48.   6.    6.
   2 737  12   0   2   5   017700.  17700.17685.17754.    0.      54.   0.   15.
   1 737  16   0   1  19   017704.  17704.17671.17917.    0.     213.   0.   33.
   2 737  16   0   2  11   017704.  17704.17703.17772.    0.      69.   0.    1.
   2 737  17   0   2   4   017705.  17705.17599.17773.    0.      68.   0.  106.
   2 738   0   6   2   3   117712.  17718.17610.17773.    0.      55.   6.  103.
   1 738  18  12   1  15   117730.  17742.17728.17911.    0.     169.  12.   14.

FIRST 1919. ARRIVALS IGNORED.
          TYPE    AV.WT.      NO.ARRIV.   TOT.IDLETIME %IDLE TIME AV SERVICE   MAXQ
         1.00      13.01       790.00   38179.92      428.65      166.16       13.00
         2.00       6.85      1127.00   30292.44      340.10       59.71        6.00

TYPE=1 QUEUE LENGTHS
   0 167
   1 299
   2 129
   3  66
   4  37
   5  25
   6  22
   7  16
   8   9
   9   6
  10   3
  11   6
  12   4
  13   1

TYPE=2 QUEUE LENGTHS
   0 229
   1 390
   2 264
   3 138
   4  72
   5  26
   6   8

TYPE=1 WAITING TIMES
   0-11.99    546         12-23.99 111         24-35.99  46
  36-47.99     28         48-59.99  22         60-71.99  21
  72-83.99      8         84-95.99   6         96-107.99      2

TYPE=2 WAITING TIMES
   0-11.99    879         12-23.99 229         24-35.99  18
```

```
   36-47.99      1
TYPE=1 IDLE TIMES
    0-11.99    358        12-23.99 153        24-35.99   51
   36-47.99     65        48-59.99  21        60-71.99   22
   72-83.99     15        84-95.99  14        96-107.99       8
  108-119.99     9      120-131.99      9        132-143.99       8
  144-155.99     5      156-167.99      3        168-179.99       1
  180-191.99     3      192-203.99      3        204-215.99       3
  216-227.99     3      228-239.99      1        240-251.99       4
  252-263.99     5      288-299.99      1        300-311.99       1
  312-323.99     1      348-359.99      3        372-383.99       1
  396-407.99     2      408-419.99      3        432-443.99       2
  444-455.99     1      456-467.99      1        600-611.99       1
  636-647.99     2      648-659.99      1        744-755.99       1
  780-791.99     1      888-899.99      1       1092-1103.99      1
1176-1187.99     1    1200-1211.99      1
TYPE=2 IDLE TIMES
    0-11.99    542        12-23.99 246        24-35.99   99
   36-47.99     53        48-59.99  45        60-71.99   29
   72-83.99     18        84-95.99  15        96-107.99      18
  108-119.99    16      120-131.99      6        132-143.99       4
  144-155.99     8      156-167.99      7        168-179.99       3
  180-191.99     1      192-203.99      1        204-215.99       4
  216-227.99     1      240-251.99      1        252-263.99       3
  276-287.99     3      384-395.99      1        408-419.99       1
  456-467.99     1      480-491.99      1
```

```
TART(2).FA(2).QUEUE(2).MAXQL(2).CQ(250.2)
  50 DIM AVLOAD(2),AVUNLOAD(2).STIME(2).TCONST(2).NOBERTHS(2).BERTH(20.2)
  60 DIM TSERV(2).SUM(2).NO(2).SUMIT(2)
  70 @%=&01000004
  80 PRINT" TYP"." DAY"." HR"." TDE". " BTH"." BTH":" Q ":
  90 @%=&01000007
 100 PRINT  " ARRIV"."ENTER"."LEFT"."LEAVE"."DELAY"."SERV"."WAIT"."IDLE"
 110 NOARRIVS=3836
 120 FDAYS=1919:NT=2:NN=1
 130 FOR T=1 TO NT:READ NOSHIPS:TCONST(T)=365*24/NOSHIPS
 140READ NOBERTHS(T).TSERV(T).STD(T):NEXTT
 150     REM***CALC.TIMEINTERVAL CONSTANT FOR EACH SHIP
 160 FOR T=1 TO NT:TCONST=TCONST(T):PROCINTERV
 170     REM***CALC TIME OF FIRST SHIP OF EACH TYPE.
 180 MAXQL(T)=0:QUEUE(T)=TRUE:START(T)=0: FA(T)=0
 190 STIME(T)=TINTERV:NEXT
 200    REM***FIND EARLIEST SHIP.
 210 GOTO220:FOR T=1 TO 3:STIME(T)=10^6:NO(T)=1:NUMB(T)=1 :NEXTT
 220 XSTIME=0:IDLET=0: STIME=10^6:FOR T=1 TO NT
 230IF STIME(T)<STIME THENSTIME=INT(STIME(T)):TYPE=T
 240 NEXT T:TPRINT=STIME
 250 HOURS=STIME MOD 24: DAYS=STIME DIV 24 :HRS=HOURS
 260 PROCDELAY(STIME)
 290 STIME=STIME+XSTIME
 300    REM*** CALC TIME TO LOAD & UNLOAD.
 310 PROCNORMAL
 320 NOBERTH=NOBERTHS(TYPE):MINDELAY=100000
 330 @%=&00000004
 340 PRINT  TYPE.DAYS.HRS.XSTIME;
 350 PROCMINDELAY
 380 ENTERB=STIME+MINDELAY:PROCQSIZE :PRINT TYPE.FIRST.QL;
 390 @%=&00020006:PRINT TPRINT,ENTERB,BERTH(FIRST.TYPE):
 400 WAITIME=MINDELAY+XSTIME
 410
 420 BERTH(FIRST.TYPE)=STIME+MINDELAY+TSERVICE :HOURS=BERTH(FIRST.TYPE) MOD 24:
LTIME=BERTH(FIRST,TYPE)
 425 HR=HOURS
 430 XSTIME=0: PROCDELAY(LTIME)
 440 TSERVICE=TSERVICE+XSTIME: BERTH(FIRST,TYPE)=BERTH(FIRST.TYPE)+XSTIME
 450 IF NN>FDAYS THEN SUMIT(TYPE)=SUMIT(TYPE)+IDLET:CQ(QL,TYPE)= CQ(QL,TYPE)+1
 460 PRINT BERTH(FIRST.TYPE):"  ":
 470 @%=&00020005:PRINT MINDELAY,TSERVICE,WAITIME,IDLET
 490 IF NN<=FDAYS GOTO 530
 500 SUM(TYPE)=SUM(TYPE)+WAITIME :NO(TYPE)=NO(TYPE)+1 : SUMSERV(TYPE)=SUMSERV(T
YPE)+TSERVICE:WT=INT(WAITIME/12):IF WT>50 THEN WT=50
 510 IT=INT(IDLET/12):IF IT>100 THEN IT=100
 520 C(WT.TYPE)=C(WT.TYPE)+1:CI(IT.TYPE)=CI(IT,TYPE)+1
 530 TCONST=TCONST(TYPE)
 540 IF NN=FDAYS THEN FDAYTIME=STIME
 550 PROCINTERV
```

```
  560 STIME(TYPE)=STIME(TYPE)+TINTERV
  570 IF NN=NOARRIVS-10 THEN VDU2
  580 NN=NN+1:IF NN<=NOARRIVS GOTO220
  590PRINT' "FIRST ";FDAYS;" ARRIVALS IGNORED."
  600 @%=&0002020B :TIMTOT=TPRINT-FDAYTIME
  610 PRINT "          TYPE    AV.WT.     NO.ARRIV.    TOT.IDLETIME %IDLE TIME AV SE
RVICE  MAXQ"
  620 FOR T=1 TO NT:PRINTT,SUM(T)/NO(T),NO(T),SUMIT(T),SUMIT(T)/TIMTOT*100,SUMSE
RV(T)/NO(T),MAXQL(T)
  630 NEXT T
  640 @%=&00000004
  645 FOR T=1 TO NT :PRINT '"TYPE=";T;" QUEUE LENGTHS"
  647 FOR IQ=0 TO MAXQL(T) :PRINT IQ,CQ(IQ,T)
  648 NEXT IQ: NEXT T
  650 FOR T=1 TO NT :PRINT'"TYPE=":T ;" WAITING TIMES"
  660 FOR IW=0 TO 100
  670 IF C(IW,T)<>0 PRINTIW*12:"-":IW*12+11.99,C(IW,T);"      "::K=K+1:IF K MOD
3=0 PRINT
  680 NEXT IW
  690 NEXT T
  700 FOR T=1 TO NT :PRINT'"TYPE=";T; " IDLE TIMES"
  710 K=0:FOR IW=0 TO 200
  720 IF CI(IW,T)<>0 PRINT IW*12:"-";IW*12+11.99,CI(IW,T);"      "::K=K+1:IF K M
OD 3=0 THENPRINT
  730 NEXT:NEXT  :PRINT
  740 @%=10:VDU3:STOP
  750 DEF PROCINTERV
  760 R=RND(1)
  770 TINTERV=-TCONST*LN(1-R)
  780 ENDPROC
  790 DEF PROCMINDELAY
  810   REM***CHECK ALL BERTHS OF THIS TYPE.
  820 FOR N=1 TO NOBERTH
  840 DELAY=BERTH(N,TYPE)-STIME
  850 IF DELAY<0 THEN MINDELAY=0 :FIRST=N :IDLET=-DELAY:GOTO870
  860 IF DELAY<MINDELAY THEN MINDELAY=DELAY:FIRST=N
  870 NEXT N
  900 ENDPROC
  940 DEF PROCNORMAL
  950 SUMN=0:FOR I=1 TO 12:R=RND(1)
  960 SUMN=SUMN+R:NEXT I
  970 TSERVICE=STD(TYPE)*(SUMN-6.0)+TSERV(TYPE)
  980 ENDPROC
  990 DEF PROCQSIZE
 1000 START=START(TYPE):FA=FA(TYPE):QUEUE=QUEUE(TYPE)
 1010 Q(FA,TYPE)=ENTERB
 1020 QEND=FA
 1040 IF TPRINT<Q(START,TYPE) GOTO 1070
 1050 IF QUEUE AND START<QEND THEN START=START+1 :GOTO 1040
 1055 IF QUEUE AND START>=QEND THEN START=0 :  FA=0:QL=0:GOTO 1160
 1060 START=START+1
 1062 IF START>ARRAYSZE THEN START=0:QUEUE=TRUE
 1064 GOTO 1040
 1070 IF QUEUE THEN QL=QEND-START+1 ELSE QL=ARRAYSZE-START+QEND+2
 1080 FA=FA+1
 1090 IF FA>ARRAYSZE THEN FA=0:QUEUE=FALSE
 1110 IF QUEUE=FALSE AND FA>START THEN PRINT"Q TOO LONG":" START="START:" FA=":F
A ;" QL=";QL
 1160 START(TYPE)=START:FA(TYPE)=FA:QUEUE(TYPE)=QUEUE
 1170 IF NN>FDAYS AND QL>MAXQL(TYPE) THEN MAXQL(TYPE)=QL
 1180 ENDPROC
 1190 DATA 804,20,161,36
 1200 DATA 1115,12,54,9
 1490 DEF  PROCDELAY(LSTIME)
 1500 PROCXSTIME(0,6,HOURS):PROCXSTIME(18,30,HOURS)
 1510 D=DAYS-NEWDAYS :IF D=0 GOTO 1560
```

```
 1520 TIDE1=(TIDE1+D) MOD 24
 1530 TIDE2=(TIDE1+6) MOD 24
 1540 TIDE3=(TIDE1+12) MOD 24
 1550 TIDE4=(TIDE1+18) MOD 24
 1560 NEWDAYS=DAYS
 1570 IF TIDE2<TIDE1 THEN PROCXSTIME(0,TIDE2,HOURS): PROCXSTIME(TIDE1,TIDE2+24,H
OURS)ELSE PROCXSTIME(TIDE1,TIDE2,HOURS)
 1580 IF TIDE4<TIDE3 THEN PROCXSTIME(0,TIDE4,HOURS):PROCXSTIME(TIDE3,TIDE4+24,HO
URS) ELSE PROCXSTIME(TIDE3,TIDE4,HOURS)
 1590 IF XST<>0 GOTO 1500
 1600 ENDPROC
 1610  DEF PROCXSTIME(T1,T2,H)
 1620 XST=0
 1630 IF H>=T1 AND H<T2 THEN XST=T2-H :XSTIME=XSTIME+XST :HOURS=(LSTIME+XSTIME)
MOD 24
 1640 ENDPROC
>RUN
   2 736  11   0   2  11    017675.   17675.17672.17747.     0.        72.   0.    3.
   2 736  21  14   2  10    117685.   17699.17684.17748.     0.        49.  14.   15.
   2 737   5   7   2   9    217693.   17700.17673.17749.     0.        49.   7.   27.
   2 737   6   6   2   8    317694.   17700.17700.17748.     0.        48.   6.    0.
   2 737  12   0   2   6    017700.   17700.17685.17754.     0.        54.   0.   15.
   1 737  16   0   1  12    017704.   17704.17656.17917.     0.       213.   0.   48.
   2 737  16   0   2  12    017704.   17704.17703.17772.     0.        68.   0.    1.
   2 737  17   0   2   5    017705.   17705.17599.17773.     0.        68.   0.  106.
   2 738   0   6   2   4    117712.   17718.17610.17773.     0.        55.   6.  108.
   1 738  18  12   1  18    117730.   17742.17719.17911.     0.       169.  12.   23.

FIRST 1919. ARRIVALS IGNORED.
        TYPE     AV.WT.      NO.ARRIV.    TOT.IDLETIME %IDLE TIME AV SERVICE  MAXQ
        1.00       9.51       790.00    47220.65      530.15      166.09       11.00
        2.00       6.10      1127.00    38894.71      436.68       59.65        6.00

TYPE=1 QUEUE LENGTHS
   0 183
   1 314
   2 140
   3  60
   4  38
   5  20
   6  14
   7   7
   8   6
   9   4
  10   2
  11   2

TYPE=2 QUEUE LENGTHS
   0 246
   1 409
   2 256
   3 135
   4  60
   5  18
   6   3

TYPE=1 WAITING TIMES
   0-11.99    594          12-23.99 112          24-35.99  33
  36-47.99     23          48-59.99  20          60-71.99   7
  72-83.99      1
TYPE=2 WAITING TIMES
   0-11.99    920          12-23.99 196
  24-35.99     11
TYPE=1 IDLE TIMES
   0-11.99    321          12-23.99 162          24-35.99  51
  36-47.99     64          48-59.99  25          60-71.99  30
```

72-83.99	12	84-95.99	18	96-107.99	8
108-119.99	13	120-131.99	9	132-143.99	10
144-155.99	5	156-167.99	2	168-179.99	3
180-191.99	3	192-203.99	2	204-215.99	1
216-227.99	3	228-239.99	3	240-251.99	2
252-263.99	6	264-275.99	1	288-299.99	2
300-311.99	3	312-323.99	3	324-335.99	1
348-359.99	3	372-383.99	1	396-407.99	2
408-419.99	1	420-431.99	1	444-455.99	1
456-467.99	1	480-491.99	1	504-515.99	1
600-611.99	2	636-647.99	1	780-791.99	1
792-803.99	1	828-839.99	1	900-911.99	1
924-935.99	2	1092-1103.99	2	1104-1115.99	1
1176-1187.99	1	1200-1211.99	2		

TYPE=2 IDLE TIMES

0-11.99	487	12-23.99	260	24-35.99	105
36-47.99	56	48-59.99	47	60-71.99	29
72-83.99	18	84-95.99	15	96-107.99	21
108-119.99	17	120-131.99	10	132-143.99	5
144-155.99	10	156-167.99	8	168-179.99	2
180-191.99	3	192-203.99	1	204-215.99	6
216-227.99	2	228-239.99	3	240-251.99	1
252-263.99	5	276-287.99	5	300-311.99	1
384-395.99	1	408-419.99	1	420-431.99	1
444-455.99	2	456-467.99	1	540-551.99	1
552-563.99	1	708-719.99	1	744-755.99	1

1998

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Variable print quality

```
>L.
  5 VDU 3
 10 R=RND(-1)
 20 ARRAYSZE=300:TIDE1=0: NEWDAYS=-1
 30 DIM SUMSERV(2),NUMB(2),STD(2),C(100,2),CI(200,2),Q(ARRAYSZE,2)
 40 DIM START(2),FA(2),QUEUE(2),MAXQL(2),CQ(300,2)
 50 DIM AVLOAD(2),AVUNLOAD(2),STIME(2),TCONST(2),NOBERTHS(2),BERTH(45,2)
 60 DIM TSERV(2),SUM(2),NO(2),SUMIT(2)
 70 @%=&01000004
 80 PRINT" TYP"," DAY"," HR"," TDE", " BTH"," BTH";" Q ";
 90 @%=&01000007
100 PRINT  " ARRIV","ENTER","LEFT","LEAVE","DELAY","SERV","WAIT","IDLE"
110 NOARRIVS=7912
120 FDAYS=3956:NT=2:NN=1
130 FOR T=1 TO NT:READ NOSHIPS:TCONST(T)=365*24/NOSHIPS
140READ NOBERTHS(T),TSERV(T),STD(T):NEXTT
150     REM***CALC.TIMEINTERVAL CONSTANT FOR EACH SHIP
160 FOR T=1 TO NT:TCONST=TCONST(T):PROCINTERV
170     REM***CALC TIME OF FIRST SHIP OF EACH TYPE.
180 MAXQL(T)=0:QUEUE(T)=TRUE:START(T)=0: FA(T)=0
190 STIME(T)=TINTERV:NEXT
200    REM***FIND EARLIEST SHIP.
210 GOTO220:FOR T=1 TO 3:STIME(T)=10^6:NO(T)=1:NUMB(T)=1 :NEXTT
220 XSTIME=0:IDLET=0: STIME=10^6:FOR T=1 TO NT
230IF STIME(T)<STIME THENSTIME=INT(STIME(T)):TYPE=T
240 NEXT T:TPRINT=STIME
250 HOURS=STIME MOD 24: DAYS=STIME DIV 24 :HRS=HOURS
260 PROCDELAY(STIME)
290 STIME=STIME+XSTIME
```

```
300   REM*** CALL TIME TO LOAD & UNLOAD.
310 PROCNORMAL
320 NOBERTH=NOBERTHS(TYPE):MINDELAY=100000
330 @%=&00000004
340 PRINT  TYPE,DAYS,HRS,XSTIME;
350 PROCMINDELAY
380 ENTERB=STIME+MINDELAY:PROCQSIZE :PRINT TYPE,FIRST,QL;
390 @%=&00020006:PRINT TPRINT,ENTERB,BERTH(FIRST,TYPE);
400 WAITIME=MINDELAY+XSTIME
410
420 BERTH(FIRST,TYPE)=STIME+MINDELAY+TSERVICE :HOURS=BERTH(FIRST,TYPE) MOD 24:
LTIME=BERTH(FIRST,TYPE)
425 HR=HOURS
430 XSTIME=0: PROCDELAY(LTIME)
440 TSERVICE=TSERVICE+XSTIME: BERTH(FIRST,TYPE)=BERTH(FIRST,TYPE)+XSTIME
450 IF NN>FDAYS THEN SUMIT(TYPE)=SUMIT(TYPE)+IDLET:CQ(QL,TYPE)= CQ(QL,TYPE)+1
460 PRINT BERTH(FIRST,TYPE);"  ";
470 @%=&00020005:PRINT MINDELAY,TSERVICE,WAITIME,IDLET
480 IF NN<=FDAYS GOTO 530
500 SUM(TYPE)=SUM(TYPE)+WAITIME :NO(TYPE)=NO(TYPE)+1 : SUMSERV(TYPE)=SUMSERV(T
YPE)+TSERVICE:WT=INT(WAITIME/12):IF WT>50 THEN WT=50
510 IT=INT(IDLET/12):IF IT>100 THEN IT=100
520 C(WT,TYPE)=C(WT,TYPE)+1:CI(IT,TYPE)=CI(IT,TYPE)+1
530 TCONST=TCONST(TYPE)
540 IF NN=FDAYS THEN FDAYTIME=STIME
550 PROCINTERV
560 STIME(TYPE)=STIME(TYPE)+TINTERV
570 IF NN=NOARRIVS-10 THEN VDU2
580 NN=NN+1:IF NN<=NOARRIVS GOTO220
590PRINT' "FIRST ";FDAYS;" ARRIVALS IGNORED."
600 @%=&0002020B :TIMTOT=TPRINT-FDAYTIME
610 PRINT "          TYPE    AV.WT.     NO.ARRIV.   TOT.IDLETIME %IDLE TIME AV SE
RVICE  MAXQ"
620 FOR T=1 TO NT:PRINTT,SUM(T)/NO(T),NO(T),SUMIT(T),SUMIT(T)/TIMTOT*100,SUMSE
RV(T)/NO(T),MAXQL(T)
630 NEXT T
640 @%=&00000004
645 FOR T=1 TO NT :PRINT '"TYPE=";T;" QUEUE LENGTHS"
647 FOR IQ=0 TO MAXQL(T) :PRINT IQ,CQ(IQ,T)
648 NEXT IQ: NEXT T
650 FOR T=1 TO NT :PRINT '"TYPE=";T ;" WAITING TIMES"
660 FOR IW=0 TO 100
670 IF C(IW,T)<>0 PRINTIW*12;"-";IW*12+11.99,C(IW,T);"        ";:K=K+1:IF K MOD
3=0 PRINT
680 NEXT IW
690 NEXT T
700 FOR T=1 TO NT :PRINT'"TYPE=";T; " IDLE TIMES"
710 K=0:FOR IW=0 TO 200
720 IF CI(IW,T)<>0 PRINT IW*12;"-";IW*12+11.99,CI(IW,T);"        ";:K=K+1:IF K M
OD 3=0 THENPRINT
730 NEXT:NEXT  :PRINT
740 @%=10:VDU3:STOP
750 DEF PROCINTERV
760 R=RND(1)
770 TINTERV=-TCONST*LN(1-R)
780 ENDPROC
790 DEF PROCMINDELAY
810   REM***CHECK ALL BERTHS OF THIS TYPE.
820 FOR N=1 TO NOBERTH
840 DELAY=BERTH(N,TYPE)-STIME
850 IF DELAY<0 THEN MINDELAY=0 :FIRST=N :IDLET=-DELAY:GOTO870
860 IF DELAY<MINDELAY THEN MINDELAY=DELAY:FIRST=N
870 NEXT N
900 ENDPROC
940 DEF PROCNORMAL
950 SUMN=0:FOR I=1 TO 12:R=RND(1)
```

```
960 LSTIME=LSTIME+NEXT I
970 TSERVICE=STD(TYPE)*(SUMN-6.0)+TSERV(TYPE)
980 ENDPROC
990 DEF PROCQSIZE
1000 START=START(TYPE):FA=FA(TYPE):QUEUE=QUEUE(TYPE)
1010 Q(FA,TYPE)=ENTERB
1020 QEND=FA
1040 IF PRINT<Q(START,TYPE) GOTO 1070
1050 IF QUEUE AND START<QEND THEN START=START+1 :GOTO 1040
1055 IF QUEUE AND START>=QEND THEN START=0 :  FA=0:QL=0:GOTO 1160
1060 START=START+1
1062 IF START>ARRAYSZE THEN START=0:QUEUE=TRUE
1064 GOTO 1040
1070 IF QUEUE THEN QL=QEND-START+1 ELSE QL=ARRAYSZE-START+QEND+2
1080 FA=FA+1
1090 IF FA>ARRAYSZE THEN FA=0:QUEUE=FALSE
1110 IF QUEUE=FALSE AND FA>START THEN PRINT"Q TOO LONG";" START="START;" FA=";F
A ;" QL=";QL
1160 START(TYPE)=START:FA(TYPE)=FA:QUEUE(TYPE)=QUEUE
1170 IF NN>FDAYS AND QL>MAXQL(TYPE) THEN MAXQL(TYPE)=QL
1180 ENDPROC
1190 DATA 1919,39,175,40
1200 DATA 2007,12,54,9
1490 DEF  PROCDELAY(LSTIME)
1500 PROCXSTIME(0,6,HOURS):PROCXSTIME(18.30,HOURS)
1510 D=DAYS-NEWDAYS :IF D=0 GOTO 1560
1520 TIDE1=(TIDE1+D) MOD 24
1530 TIDE2=(TIDE1+6) MOD 24
1540 TIDE3=(TIDE1+12) MOD 24
1550 TIDE4=(TIDE1+18) MOD 24
1560 NEWDAYS=DAYS
1570 IF TIDE2<TIDE1 THEN PROCXSTIME(0,TIDE2,HOURS): PROCXSTIME(TIDE1,TIDE2+24,H
OURS ELSE PROCXSTIME(TIDE1,TIDE2,HOURS)
1580 IF TIDE4<TIDE3 THEN PROCXSTIME(0,TIDE4,HOURS):PROCXSTIME(TIDE3,TIDE4+24,HO
URS) ELSE PROCXSTIME(TIDE3,TIDE4,HOURS)
1590 IF XST<>0 GOTO 1500
1600 ENDPROC
1610  DEF PROCXSTIME(T1,T2,H)
1620  XST=0
1630 IF H>=T1 AND H<T2 THEN XST=T2-H :XSTIME=XSTIME+XST :HOURS=(LSTIME+XSTIME)
MOD 24
1640 ENDPROC
RUN
  1 728    1    5    1   18  6517473.   17771.17771.17959.   293.      188. 298.    0.
  2 728    1    5    2   12 27017473.   18686.18686.18759.  1208.       74.1213.    0.
  2 728    1    5    2    1 27117473.   18702.18702.18775.  1224.       73.1229.    0.
  1 728    5    1    1   15  6617477.   17771.17771.17982.   293.      211. 294.    0.
  2 728    9    6    2    2 26517481.   18703.18703.18751.  1216.       48.1222.    0.
  2 728   11    4    2    3 26617483.   18703.18703.18751.  1216.       47.1220.    0.
  2 728   13    2    2    8 26617485.   18726.18726.18799.  1239.       72.1241.    0.
  2 728   15    0    2    7 26717487.   18726.18726.18799.  1239.       72.1239.    0.
  2 728   15    0    2   10 26817487.   18727.18727.18784.  1240.       57.1240.    0.
  2 728   17    0    2    5 26917489.   18727.18727.18798.  1238.       72.1238.    0.

FIRST 3956. ARRIVALS IGNORED.
       TYPE      AV.WT.       NO.ARRIV.    TOT.IDLETIME %IDLE TIME AV SERVICE  MAXQ
       1.00      168.65       1871.00        0.00         0.00      180.06      75.00
       2.00      673.30       2085.00        0.00         0.00       59.55     271.00

TYPE=1 QUEUE LENGTHS
    0    0
    1    0
    2    0
    3    0
    4    0
    5    0
```

6	0
7	0
8	0
9	0
10	0
11	0
12	0
13	0
14	2
15	9
16	13
17	29
18	36
19	44
20	43
21	47
22	50
23	53
24	63
25	63
26	76
27	69
28	54
29	40
30	41
31	50
32	45
33	54
34	52
35	51
36	39
37	43
38	42
39	43
40	44
41	36
42	42
43	41
44	35
45	25
46	23
47	29
48	25
49	29
50	30
51	28
52	26
53	32
54	33
55	30
56	19
57	20
58	20
59	15
60	16
61	15
62	12
63	7
64	11
65	8
66	6
67	3
68	2
69	4
70	11
71	12

73	9
74	7
75	5

TYPE=2 QUEUE LENGTHS

0	0
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0
18	0
19	0
20	0
21	0
22	0
23	0
24	0
25	0
26	0
27	0
28	0
29	0
30	0
31	0
32	0
33	0
34	0
35	0
36	0
37	0
38	0
39	0
40	0
41	0
42	0
43	0
44	0
45	0
46	0
47	0
48	0
49	0
50	0
51	0
52	0
53	0
54	0
55	0
56	0
57	0
58	0
59	0

60	0
61	0
62	0
63	1
64	4
65	4
66	6
67	5
68	6
69	9
70	9
71	6
72	7
73	10
74	12
75	21
76	18
77	15
78	10
79	8
80	9
81	7
82	4
83	3
84	6
85	10
86	10
87	11
88	16
89	17
90	18
91	20
92	25
93	26
94	30
95	36
96	33
97	29
98	26
99	20
100	20
101	12
102	7
103	12
104	12
105	17
106	18
107	32
108	31
109	33
110	28
111	25
112	23
113	20
114	22
115	21
116	17
117	14
118	9
119	10
120	11
121	20
122	20
123	19
124	19
125	16

126	[illegible]
127	8
128	5
129	4
130	3
131	5
132	7
133	8
134	6
135	11
136	12
137	18
138	19
139	21
140	22
141	12
142	10
143	15
144	14
145	12
146	13
147	14
148	17
149	15
150	12
151	7
152	9
153	10
154	6
155	4
156	4
157	7
158	6
159	4
160	5
161	7
162	7
163	6
164	3
165	3
166	5
167	5
168	3
169	2
170	2
171	3
172	4
173	5
174	3
175	3
176	2
177	1
178	2
179	4
180	4
181	3
182	7
183	8
184	13
185	9
186	4
187	5
188	5
189	6
190	12
191	14

192	14
193	15
194	10
195	12
196	13
197	19
198	14
199	11
200	8
201	7
202	6
203	11
204	10
205	9
206	8
207	9
208	7
209	7
210	5
211	8
212	6
213	4
214	5
215	5
216	4
217	3
218	3
219	2
220	2
221	3
222	5
223	6
224	10
225	9
226	12
227	8
228	11
229	13
230	9
231	6
232	3
233	6
234	6
235	6
236	3
237	3
238	5
239	3
240	3
241	6
242	7
243	4
244	6
245	5
246	5
247	6
248	8
249	7
250	11
251	8
252	8
253	6
254	5
255	3
256	13
257	14

```
259  10
260  10
261   8
262   8
263   5
264   4
265   3
266   4
267   3
268   2
269   2
270   1
271   1

TYPE=1 WAITING TIMES
  36-47.99      1          48-59.99    3          60-71.99   25
  72-83.99     98          84-95.99 109           96-107.99     157
 108-119.99   143         120-131.99      138        132-143.99      117
 144-155.99   109         156-167.99      134        168-179.99      133
 180-191.99   102         192-203.99       85        204-215.99       76
 216-227.99    76         228-239.99       66        240-251.99       64
 252-263.99    66         264-275.99       58        276-287.99       20
 288-299.99    21         300-311.99       27        312-323.99       22
 324-335.99    22         336-347.99        9
TYPE=2 WAITING TIMES
 276-287.99     4
 288-299.99    15         300-311.99       17        312-323.99       21
 324-335.99    37         336-347.99       35        348-359.99       28
 360-371.99    18         372-383.99       10        384-395.99       24
 396-407.99    43         408-419.99       65        420-431.99       96
 432-443.99    78         444-455.99       43        456-467.99       41
 468-479.99    40         480-491.99       71        492-503.99       53
 504-515.99    48         516-527.99       47        528-539.99       38
 540-551.99    31         552-563.99       45        564-575.99       48
 576-587.99    32         588-599.99       21        600-611.99     1036

TYPE=1 IDLE TIMES
   0-11.99   1871
TYPE=2 IDLE TIMES
   0-11.99   2085
>L.
    5 VDU 3
   10 R=RND(-1)
   20 ARRAYSZE=300:TIDE1=0: NEWDAYS=-1
   30 DIM SUMSERV(2),NUMB(2),STD(2),C(100,2),CI(200,2),Q(ARRAYSZE,2)
   40 DIM START(2),FA(2),QUEUE(2),MAXQL(2),CQ(300,2)
   50 DIM AVLOAD(2),AVUNLOAD(2),STIME(2),TCONST(2),NOBERTHS(2),BERTH(45,2)
   60 DIM TSERV(2),SUM(2),NO(2),SUMIT(2)
   70 @%=&01000004
   80 PRINT" TYP"," DAY"," HR"," IDE", " BTH"," BTH";" Q ";
   90 @%=&01000007
  100 PRINT  " ARRIV","ENTER","LEFT","LEAVE","DELAY","SERV","WAIT","IDLE"
  110 NOARRIVS=7912
  120 FDAYS=3956:NT=2:NN=1
  130 FOR T=1 TO NT:READ NOSHIPS:TCONST(T)=365*24/NOSHIPS
  140READ NOBERTHS(T),TSERV(T),STD(T):NEXTT
  150    REM***CALC.TIMEINTERVAL CONSTANT FOR EACH SHIP
  160 FOR T=1 TO NT:TCONST=TCONST(T):PROCINTERV
  170    REM***CALC TIME OF FIRST SHIP OF EACH TYPE.
  180 MAXQL(T)=0:QUEUE(T)=TRUE:START(T)=0: FA(T)=0
  190 STIME(T)=TINTERV:NEXT
  200    REM***FIND EARLIEST SHIP.
  210 GOTO220:FOR I=1 TO 3:STIME(T)=10^6:NO(T)=1:NUMB(T)=1 :NEXTT
  220 XSTIME=0:IDLET=0: STIME=10^6:FOR T=1 TO NT
  230IF STIME(T)<STIME THENSTIME=INT(STIME(T)):TYPE=T
```

```
24? NEXT I:PRINT=STIME
250 HOURS=STIME MOD 24: DAYS=STIME DIV 24 :HRS=HOURS
260 PROCDELAY(STIME)
290 STIME=STIME+XSTIME
300   REM*** CALC TIME TO LOAD & UNLOAD.
310 PROCNORMAL
320 NOBERTH=NOBERTHS(TYPE):MINDELAY=100000
330 @%=&00000004
340 PRINT  TYPE,DAYS,HRS,XSTIME;
350 PROCMINDELAY
380 ENTERB=STIME+MINDELAY:PROCQSIZE :PRINT TYPE,FIRST,QL;
390 @%=&00020006:PRINT TPRINT,ENTERB,BERTH(FIRST,TYPE);
400 WAITIME=MINDELAY+XSTIME
410
420 BERTH(FIRST,TYPE)=STIME+MINDELAY+TSERVICE :HOURS=BERTH(FIRST,TYPE) MOD 24:
 LTIME=BERTH(FIRST,TYPE)
425 HR=HOURS
430 XSTIME=0: PROCDELAY(LTIME)
440 TSERVICE=TSERVICE+XSTIME: BERTH(FIRST,TYPE)=BERTH(FIRST,TYPE)+XSTIME
450 IF NN>FDAYS THEN SUMIT(TYPE)=SUMIT(TYPE)+IDLET:CQ(QL,TYPE)= CQ(QL,TYPE)+1
460 PRINT BERTH(FIRST,TYPE);"  ";
470 @%=&00020005:PRINT MINDELAY,TSERVICE,WAITIME,IDLET
490 IF NN<=FDAYS GOTO 530
500 SUM(TYPE)=SUM(TYPE)+WAITIME :NO(TYPE)=NO(TYPE)+1 : SUMSERV(TYPE)=SUMSERV(T
YPE)+TSERVICE:WT=INT(WAITIME/12):IF WT>50 THEN WT=50
510 IT=INT(IDLET/12):IF IT>100 THEN IT=100
520 C(WT,TYPE)=C(WT,TYPE)+1:CI(IT,TYPE)=CI(IT,TYPE)+1
530 TCONST=TCONST(TYPE)
540 IF NN=FDAYS THEN FDAYTIME=STIME
550 PROCINTERV
560 STIME(TYPE)=STIME(TYPE)+TINTERV
570 IF NN=NOARRIVS-10 THEN VDU2
580 NN=NN+1:IF NN<=NOARRIVS GOTO220
590PRINT' "FIRST ";FDAYS;" ARRIVALS IGNORED."
600 @%=&0002020B :TIMTOT=TPRINT-FDAYTIME
610 PRINT "         TYPE    AV.WT.      NO.ARRIV.   TOT.IDLETIME %IDLE TIME AV SE
RVICE  MAXQ"
620 FOR T=1 TO NT:PRINTT,SUM(T)/NO(T),NO(T),SUMIT(T),SUMIT(T)/TIMTOT*100,SUMSE
RV(T)/NO(T),MAXQL(T)
630 NEXT T
640 @%=&00000004
645 FOR T=1 TO NT :PRINT '"TYPE=";T;" QUEUE LENGTHS"
647 FOR IQ=0 TO MAXQL(T) :PRINT IQ,CQ(IQ,T)
648 NEXT IQ: NEXT T
650 FOR T=1 TO NT :PRINT'"TYPE=";T ;" WAITING TIMES"
660 FOR IW=0 TO 100
670 IF C(IW,T)<>0 PRINTIW*12;"-";IW*12+11.99,C(IW,T);"       ";:K=K+1:IF K MOD
3=0 PRINT
680 NEXT IW
690 NEXT T
700 FOR T=1 TO NT :PRINT'"TYPE=";T; " IDLE TIMES"
710 K=0:FOR IW=0 TO 200
720 IF CI(IW,T)<>0 PRINT IW*12;"-";IW*12+11.99,CI(IW,T);"       ";:K=K+1:IF K M
OD 3=0 THENPRINT
730 NEXT:NEXT  :PRINT
740 @%=10:VDU3:STOP
750 DEF PROCINTERV
760 R=RND(1)
770 TINTERV=-TCONST*LN(1-R)
780 ENDPROC
790 DEF PROCMINDELAY
810   REM***CHECK ALL BERTHS OF THIS TYPE.
820 FOR N=1 TO NOBERTH
840 DELAY=BERTH(N,TYPE)-STIME
850 IF DELAY<0 THEN MINDELAY=0 :FIRST=N :IDLET=-DELAY:GOTO870
860 IF DELAY<MINDELAY THEN MINDELAY=DELAY:FIRST=N
```

```
 900 ENDPROC
 940 DEF PROCNORMAL
 950 SUMN=0:FOR I=1 TO 12:R=RND(1)
 960 SUMN=SUMN+R:NEXT I
 970 TSERVICE=STD(TYPE)*(SUMN-6.0)+TSERV(TYPE)
 980 ENDPROC
 990 DEF PROCQSIZE
1000 START=START(TYPE):FA=FA(TYPE):QUEUE=QUEUE(TYPE)
1010 Q(FA,TYPE)=ENTERB
1020 QEND=FA
1040 IF TPRINT<Q(START,TYPE) GOTO 1070
1050 IF QUEUE AND START<QEND THEN START=START+1 :GOTO 1040
1055 IF QUEUE AND START>=QEND THEN START=0 :  FA=0:QL=0:GOTO 1160
1060 START=START+1
1062 IF START>ARRAYSZE THEN START=0:QUEUE=TRUE
1064 GOTO 1040
1070 IF QUEUE THEN QL=QEND-START+1 ELSE QL=ARRAYSZE-START+QEND+2
1080 FA=FA+1
1090 IF FA>ARRAYSZE THEN FA=0:QUEUE=FALSE
1110 IF QUEUE=FALSE AND FA>START THEN PRINT"Q TOO LONG";" START="START;" FA=";F
A ;" QL=";QL
1160 START(TYPE)=START:FA(TYPE)=FA:QUEUE(TYPE)=QUEUE
1170 IF NN>FDAYS AND QL>MAXQL(TYPE) THEN MAXQL(TYPE)=QL
1180 ENDPROC
1190 DATA 1919,40,175,40
1200 DATA 2037,14,54,9
1490 DEF  PROCDELAY(LSTIME)
1500 PROCXSTIME(0,6,HOURS):PROCXSTIME(18,30,HOURS)
1510 D=DAYS-NEWDAYS :IF D=0 GOTO 1560
1520 TIDE1=(TIDE1+D) MOD 24
1530 TIDE2=(TIDE1+6) MOD 24
1540 TIDE3=(TIDE1+12) MOD 24
1550 TIDE4=(TIDE1+18) MOD 24
1560 NEWDAYS=DAYS
1570 IF TIDE2<TIDE1 THEN PROCXSTIME(0,TIDE2,HOURS): PROCXSTIME(TIDE1,TIDE2+24.H
OURS)ELSE PROCXSTIME(TIDE1,TIDE2,HOURS)
1580 IF TIDE4<TIDE3 THEN PROCXSTIME(0,TIDE4,HOURS):PROCXSTIME(TIDE3,TIDE4+24
URS) ELSE PROCXSTIME(TIDE3,TIDE4,HOURS)
1590 IF XST<>0 GOTO 1500
1600 ENDPROC
1610  DEF PROCXSTIME(T1,T2,H)
1620 XST=0
1630 IF H>=T1 AND H<T2 THEN XST=T2-H :XSTIME=XSTIME+XST :HOURS=(LSTIME+XSTIME)
MOD 24
1640 ENDPROC
>RUN
   1 728   1   5   1  26  3317473.  17623.17623.17815.   145.     192. 150.   0.
   2 728   1   5   2  10  7817473.  17797.17797.17871.   319.      74. 324.   0.
   2 728   1   5   2   3  7917473.  17797.17797.17862.   319.      65. 324.   0.
   1 728   5   1   1  38  3417477.  17624.17624.17839.   146.     214. 147.   0.
   2 728   9   6   2   6  8017481.  17815.17815.17863.   328.      48. 334.   0.
   2 728  11   4   2  12  8117483.  17815.17815.17862.   328.      47. 332.   0.
   2 728  13   2   2   2  7717485.  17816.17816.17886.   329.      70. 331.   0.
   2 728  15   0   2   4  7717487.  17823.17823.17887.   336.      64. 336.   0.
   2 728  15   0   2   7  7817487.  17838.17838.17895.   351.      57. 351.   0.
   2 728  17   0   2   1  7817489.  17838.17838.17910.   349.      72. 349.   0.

FIRST 3956. ARRIVALS IGNORED.
        TYPE    AV.WT.      NO.ARRIV.   TOT.IDLETIME %IDLE TIME AV SERVICE  MAXQ
        1.00     67.22      1871.00     5319.39        61.91      180.16      52.00
        2.00    101.09      2085.00      953.92        11.10       59.49      81.00

TYPE=1 QUEUE LENGTHS
   0  52
   1  87
```

2	74
3	92
4	71
5	67
6	62
7	63
8	60
9	64
10	46
11	61
12	63
13	57
14	54
15	64
16	49
17	52
18	51
19	47
20	47
21	41
22	45
23	39
24	27
25	22
26	29
27	34
28	32
29	31
30	35
31	34
32	31
33	25
34	22
35	12
36	18
37	9
38	12
39	13
40	13
41	7
42	5
43	4
44	3
45	4
46	7
47	3
48	4
49	3
50	4
51	2
52	1

FF=2 QUEUE LENGTHS

0	18
1	29
2	47
3	66
4	59
5	62
6	82
7	80
8	87
9	102
10	96
11	96
12	93

13	[illegible]
14	69
15	57
16	52
17	45
18	47
19	32
20	30
21	23
22	12
23	12
24	14
25	13
26	10
27	8
28	6
29	4
30	4
31	6
32	7
33	10
34	17
35	21
36	26
37	27
38	25
39	29
40	29
41	30
42	28
43	21
44	21
45	12
46	10
47	6
48	3
49	4
50	3
51	3
52	3
53	12
54	15
55	12
56	14
57	17
58	16
59	11
60	7
61	10
62	9
63	9
64	11
65	11
66	10
67	9
68	8
69	10
70	15
71	16
72	16
73	17
74	19
75	16
76	10
77	12
78	7

```
  7     2
 80     1
 81     1

TYPE=1 WAITING TIMES
   0-11.99    302          12-23.99 190           24-35.99 147
  36-47.99    133          48-59.99 192           60-71.99 148
  72-83.99    119          84-95.99 119           96-107.99      95
 108-119.99    86         120-131.99        94        132-143.99        77
 144-155.99    56         156-167.99        31        168-179.99        24
 180-191.99    21         192-203.99        24        204-215.99        11
 216-227.99     2
TYPE=2 WAITING TIMES
   0-11.99    146          12-23.99 194
  24-35.99    246          36-47.99 258           48-59.99 195
  60-71.99    170          72-83.99 109           84-95.99  50
  96-107.99    29         108-119.99        21        120-131.99         9
 132-143.99    27         144-155.99        54        156-167.99        95
 168-179.99    71         180-191.99        47        192-203.99        17
 204-215.99    13         216-227.99        27        228-239.99        44
 240-251.99    32         252-263.99        30        264-275.99        24
 276-287.99    20         288-299.99        48        300-311.99        45
 312-323.99    34         324-335.99        25        336-347.99         3
 348-359.99     2
TYPE=1 IDLE TIMES
   0-11.99   1730          12-23.99  94           24-35.99  15
  36-47.99     10          48-59.99   3           60-71.99   5
  72-83.99      2          84-95.99   5           96-107.99        1
 108-119.99     1         120-131.99         1        144-155.99         2
 156-167.99     1         168-179.99         1
TYPE=2 IDLE TIMES
   0-11.99   2051          12-23.99  21           24-35.99   8
  36-47.99      2          48-59.99   3
>L.
    5 VDU 3
   10 R=RND(-1)
   20 ARRAYSZE=300:TIDE1=0: NEWDAYS=-1
   30 DIM SUMSERV(2),NUMB(2),STD(2),C(100,2),CI(200,2),Q(ARRAYSZE,2)
   40 DIM START(2),FA(2),QUEUE(2),MAXQL(2),CQ(300,2)
   50 DIM AVLOAD(2),AVUNLOAD(2),STIME(2),TCONST(2),NOBERTHS(2),BERTH(45,2)
   60 DIM TSERV(2),SUM(2),NO(2),SUMIT(2)
   70 @%=&01000004
   80 PRINT" TYP"," DAY"," HR"," TDE",." BTH"," BTH";" Q ";
   90 @%=&01000007
  100 PRINT  " ARRIV","ENTER","LEFT","LEAVE","DELAY","SERV","WAIT","IDLE"
  110 NOARRIVS=7912
  120 FDAYS=3956:NT=2:NN=1
  130 FOR T=1 TO NT:READ NOSHIPS:TCONST(T)=365*24/NOSHIPS
  140READ NOBERTHS(T),TSERV(T),STD(T):NEXTT
  150     REM***CALC.TIMEINTERVAL CONSTANT FOR EACH SHIP
  160 FOR T=1 TO NT:TCONST=TCONST(T):PROCINTERV
  170     REM***CALC TIME OF FIRST SHIP OF EACH TYPE.
  180 MAXQL(T)=0:QUEUE(T)=TRUE:START(T)=0: FA(T)=0
  190 STIME(T)=TINTERV:NEXT
  200    REM***FIND EARLIEST SHIP.
  210 GOTO220:FOR T=1 TO 3:STIME(T)=10^6:NO(T)=1:NUMB(T)=1 :NEXTT
  220 XSTIME=0:IDLET=0: STIME=10^6:FOR T=1 TO NT
  230IF STIME(T)<STIME THENSTIME=INT(STIME(T)):TYPE=T
  240 NEXT T:TPRINT=STIME
  250 HOURS=STIME MOD 24: DAYS=STIME DIV 24 :HRS=HOURS
  260 PROCDELAY(STIME)
  290 STIME=STIME+XSTIME
  300    REM*** CALC TIME TO LOAD & UNLOAD.
  310 PROCNORMAL
  320 NOBERTH=NOBERTHS(TYPE):MINDELAY=100000
  330 @%=&0000004
```

```
... PRINT ...FIRST,...,HRS,XSTIME;
350 PROCMINDELAY
380 ENTERB=STIME+MINDELAY:PROCQSIZE :PRINT TYPE,FIRST,QL;
390 @%=&00020006:PRINT TPRINT,ENTERB,BERTH(FIRST,TYPE);
400 WAITIME=MINDELAY+XSTIME
410
420 BERTH(FIRST,TYPE)=STIME+MINDELAY+TSERVICE :HOURS=BERTH(FIRST,TYPE) MOD 24:
LTIME=BERTH(FIRST,TYPE)
425 HR=HOURS
430 XSTIME=0: PROCDELAY(LTIME)
440 TSERVICE=TSERVICE+XSTIME: BERTH(FIRST,TYPE)=BERTH(FIRST,TYPE)+XSTIME
450 IF NN>FDAYS THEN SUMIT(TYPE)=SUMIT(TYPE)+IDLET:CQ(QL,TYPE)=CQ(QL,TYPE)+1
460 PRINT BERTH(FIRST,TYPE);"  ";
470 @%=&00020005:PRINT MINDELAY,TSERVICE,WAITIME,IDLET
490 IF NN<=FDAYS GOTO 530
500 SUM(TYPE)=SUM(TYPE)+WAITIME :NO(TYPE)=NO(TYPE)+1 : SUMSERV(TYPE)=SUMSERV(T
YPE)+TSERVICE:WT=INT(WAITIME/12):IF WT>50 THEN WT=50
510 IT=INT(IDLET/12):IF IT>100 THEN IT=100
520 C(WT,TYPE)=C(WT,TYPE)+1:CI(IT,TYPE)=CI(IT,TYPE)+1
530 TCONST=TCONST(TYPE)
540 IF NN=FDAYS THEN FDAYTIME=STIME
550 PROCINTERV
560 STIME(TYPE)=STIME(TYPE)+TINTERV
570 IF NN=NOARRIVS-10 THEN VDU2
580 NN=NN+1:IF NN<=NOARRIVS GOTO220
590PRINT' "FIRST ";FDAYS;" ARRIVALS IGNORED."
600 @%=&0002020B :TIMTOT=TPRINT-FDAYTIME
610 PRINT "          TYPE    AV.WT.      NO.ARRIV.    TOT.IDLETIME %IDLE TIME AV SE
RVICE   MAXQ"
620 FOR T=1 TO NT:PRINTT,SUM(T)/NO(T),NO(T),SUMIT(T),SUMIT(T)/TIMTOT*100,SUMSE
RV(T)/NO(T),MAXQL(T)
630 NEXT T
640 @%=&00000004
645 FOR T=1 TO NT :PRINT '"TYPE=";T;" QUEUE LENGTHS"
647 FOR IQ=0 TO MAXQL(T) :PRINT IQ,CQ(IQ,T)
648 NEXT IQ: NEXT T
650 FOR T=1 TO NT :PRINT'"TYPE=";T ;" WAITING TIMES"
660 FOR IW=0 TO 100
670 IF C(IW,T)<>0 PRINTIW*12;"-";IW*12+11.99,C(IW,T);"       ";:K=K+1:IF K MOD
3=0 PRINT
680 NEXT IW
690 NEXT T
700 FOR T=1 TO NT :PRINT'"TYPE=";T; " IDLE TIMES"
710 K=0:FOR IW=0 TO 200
720 IF CI(IW,T)<>0 PRINT IW*12;"-";IW*12+11.99,CI(IW,T);"       ";:K=K+1:IF K M
OD 3=0 THENPRINT
730 NEXT:NEXT  :PRINT
740 @%=10:VDU3:STOP
750 DEF PROCINTERV
760 R=RND(1)
770 TINTERV=-TCONST*LN(1-R)
790 ENDPROC
800 DEF PROCMINDELAY
810   REM***CHECK ALL BERTHS OF THIS TYPE.
820 FOR N=1 TO NOBERTH
840 DELAY=BERTH(N,TYPE)-STIME
850 IF DELAY<0 THEN MINDELAY=0 :FIRST=N :IDLET=-DELAY:GOTO870
860 IF DELAY<MINDELAY THEN MINDELAY=DELAY:FIRST=N
870 NEXT N
900 ENDPROC
940 DEF PROCNORMAL
950 SUMN=0:FOR I=1 TO 12:R=RND(1)
960 SUMN=SUMN+R:NEXT I
970 TSERVICE=STD(TYPE)*(SUMN-6.0)+TSERV(TYPE)
980 ENDPROC
990 DEF PROCQSIZE
```

```
1000 START=START(TYPE):FA=FA(TYPE):QUEUE=QUEUE(TYPE)
1010 Q(FA,TYPE)=ENTERB
1020 QEND=FA
1040 IF TPRINT<Q(START,TYPE) GOTO 1070
1050 IF QUEUE AND START<QEND THEN START=START+1 :GOTO 1040
1055 IF QUEUE AND START>=QEND THEN START=0 :  FA=0:QL=0:GOTO 1160
1060 START=START+1
1062 IF START>ARRAYSZE THEN START=0:QUEUE=TRUE
1064 GOTO 1040
1070 IF QUEUE THEN QL=QEND-START+1 ELSE QL=ARRAYSZE-START+QEND+2
1080 FA=FA+1
1090 IF FA>ARRAYSZE THEN FA=0:QUEUE=FALSE
1110 IF QUEUE=FALSE AND FA>START THEN PRINT"Q TOO LONG";" START=";START;" FA=";F
A ;" QL=";QL
1160 START(TYPE)=START:FA(TYPE)=FA:QUEUE(TYPE)=QUEUE
1170 IF NN>FDAYS AND QL>MAXQL(TYPE) THEN MAXQL(TYPE)=QL
1180 ENDPROC
1190 DATA 1919,41.175,40
1200 DATA 2037,15,54,9
1490 DEF  PROCDELAY(LSTIME)
1500 PROCXSTIME(0,6,HOURS):PROCXSTIME(18,30,HOURS)
1510 D=DAYS-NEWDAYS :IF D=0 GOTO 1560
1520 TIDE1=(TIDE1+D) MOD 24
1530 TIDE2=(TIDE1+6) MOD 24
1540 TIDE3=(TIDE1+12) MOD 24
1550 TIDE4=(TIDE1+18) MOD 24
1560 NEWDAYS=DAYS
1570 IF TIDE2<TIDE1 THEN PROCXSTIME(0,TIDE2,HOURS): PROCXSTIME(TIDE1,TIDE2+24,H
OURS)ELSE PROCXSTIME(TIDE1,TIDE2,HOURS)
1580 IF TIDE4<TIDE3 THEN PROCXSTIME(0,TIDE4,HOURS):PROCXSTIME(TIDE3,TIDE4+24,HO
URS) ELSE PROCXSTIME(TIDE3,TIDE4,HOURS)
1590 IF XST<>0 GOTO 1500
1600 ENDPROC
1610  DEF PROCXSTIME(T1,T2,H)
1620 XST=0
1630 IF H>=T1 AND H<T2 THEN XST=T2-H :XSTIME=XSTIME+XST :HOURS=(LSTIME+XSTIME)
MOD 24
1640 ENDPROC
>RUN
  1 728   1   5   1  37  1917473.  17553.17553.17742.   75.    189.  80.   0.
  2 728   1   5   2  10  1517473.  17532.17532.17607.   54.     75.  59.   0.
  2 728   1   5   2  11  1617473.  17534.17534.17598.   56.     65.  61.   0.
  1 728   5   1   1  20  2017477.  17554.17554.17767.   76.    213.  77.   0.
  2 728   9   6   2   2  1717481.  17534.17534.17583.   47.     49.  53.   0.
  2 728  11   4   2   1  1717483.  17550.17550.17599.   63.     48.  67.   0.
  2 728  13   2   2   5  1717485.  17551.17551.17623.   64.     72.  66.   0.
  2 728  15   0   2  15  1817487.  17551.17551.17622.   64.     71.  64.   0.
  2 728  15   0   2   9  1917487.  17559.17559.17623.   72.     64.  72.   0.
  2 728  17   0   2   8  1917489.  17559.17559.17623.   70.     64.  70.   0.

FIRST 3956. ARRIVALS IGNORED.
      TYPE    AV.WT.     NO.ARRIV.   TOT.IDLETIME %IDLE TIME AV SERVICE  MAXQ
      1.00     37.74     1871.00    13791.26      160.51      180.15     41.00
      2.00     26.82     2085.00     5856.87       68.17       59.54     30.00

TYPE=1 QUEUE LENGTHS
   0 118
   1 184
   2 161
   3 134
   4 117
   5 1[illegible]
   6 1[illegible]
   7  [illegible]5
   8  94
   9   [illegible]
```

10	[illegible]
11	57
12	35
13	51
14	46
15	40
16	36
17	32
18	24
19	23
20	24
21	23
22	25
23	18
24	18
25	19
26	19
27	11
28	12
29	7
30	10
31	7
32	5
33	6
34	8
35	6
36	6
37	4
38	5
39	5
40	5
41	2

TYPE=2 QUEUE LENGTHS

0	91
1	158
2	180
3	190
4	187
5	169
6	155
7	142
8	112
9	92
10	91
11	75
12	70
13	63
14	66
15	62
16	53
17	37
18	23
19	18
20	15
21	10
22	7
23	7
24	4
25	3
26	1
27	1
28	1
29	1
30	1

```
TYPE=1 WAITING TIMES
  0-11.99    599        12-23.99 308          24-35.99 232
 36-47.99    187        48-59.99 122          60-71.99 105
 72-83.99     97        84-95.99  78          96-107.99     36
108-119.99    31       120-131.99       15       132-143.99      24
144-155.99    32       156-167.99       13       168-179.99       2

TYPE=2 WAITING TIMES
  0-11.99    610        12-23.99 537          24-35.99 324
 36-47.99    239        48-59.99 211          60-71.99 102
 72-83.99     31        84-95.99  16          96-107.99     11
108-119.99     4
TYPE=1 IDLE TIMES
  0-11.99   1565        12-23.99 173          24-35.99  31
 36-47.99     32        48-59.99   6          60-71.99  16
 72-83.99     10        84-95.99  15          96-107.99      1
108-119.99     4       120-131.99        5       132-143.99       2
144-155.99     3       156-167.99        3       168-179.99       1
192-203.99     1       204-215.99        1       264-275.99       1
288-299.99     1
TYPE=2 IDLE TIMES
  0-11.99   1927        12-23.99 102          24-35.99  23
 36-47.99     11        48-59.99   2          60-71.99   5
 72-83.99      3        84-95.99   2         108-119.99      3
120-131.99     2       132-143.99        2       168-179.99       1
204-215.99     1       240-251.99        1
>L.
    5 VDU 3
   10 A=RND(-1)
   20 ARRAYSIZE=300:TIDE1=0: NEWDAYS=-1
   30 DIM SUMSERV(2),NUMB(2),STD(2),C(100,2),CI(200,2),Q(ARRAYSZE,2)
   40 DIM START(2),FA(2),QUEUE(2),MAXQL(2),CQ(300,2)
   50 DIM AVLOAD(2),AVUNLOAD(2),STIME(2),TCONST(2),NOBERTHS(2),BERTH(45,2)
   60 DIM TSERV(2),SUM(2),NU(2),SUMIT(2)
   70 @%=&01000004
   80 PRINT" TYP"," DAY"," HR"," TDE", " BTH"," BTH";" Q ";
   90 @%=&01000007
  100 PRINT  " ARRIV","ENTER","LEFT","LEAVE","DELAY","SERV","WAIT","IDLE"
  110 NOARRIVS=7912
  120 FDAYS=3956:NT=2:NN=1
  130 FOR T=1 TO NT:READ NOSHIPS:TCONST(T)=365*24/NOSHIPS
  140 READ NOBERTHS(T),TSERV(T),STD(T):NEXTT
  150     REM***CALC.TIMEINTERVAL CONSTANT FOR EACH SHIP
  160 FOR T=1 TO NT:TCONST=TCONST(T):PROCINTERV
  170     REM***CALC TIME OF FIRST SHIP OF EACH TYPE.
  180 MAXQL(T)=0:QUEUE(T)=TRUE:START(T)=0: FA(T)=0
  190 STIME(T)=TINTERV:NEXT
  200    REM***FIND EARLIEST SHIP.
  210 GOTO220:FOR T=1 TO 3:STIME(T)=10^6:NO(T)=1:NUMB(T)=1 :NEXTT
  220 XSTIME=0:IDLET=0: STIME=10^6:FOR T=1 TO NT
  230 IF STIME(T)<STIME THENSTIME=INT(STIME(T)):TYPE=T
  240 NEXT T:TPRINT=STIME
  250 HOURS=STIME MOD 24: DAYS=STIME DIV 24 :HRS=HOURS
  260 PROCDELAY(STIME)
  290 STIME=STIME+XSTIME
  300    REM*** CALC TIME TO LOAD & UNLOAD.
  310 PROCNORMAL
  320 NOBERTH=NOBERTHS(TYPE):MINDELAY=100000
  330 @%=&00000004
  340 PRINT  TYPE,DAYS,HRS,XSTIME;
  350 PROCMINDELAY
  380 ENTERB=STIME+MINDELAY:PROCQSIZE :PRINT TYPE,FIRST,QL;
  390 @%=&00020006:PRINT TPRINT,ENTERB,BERTH(FIRST,TYPE);
  400 WAITIME=MINDELAY+XSTIME
  410
  420 BERTH(FIRST,TYPE)=STIME+MINDELAY+TSERVICE :HOURS=BERTH(FIRST,TYPE) MOD 24:
```

```
...QL=BERTH(FIRST,TYPE)
  425 HR=HOURS
  430 XSTIME=0: PROCDELAY(LTIME)
  440 TSERVICE=TSERVICE+XSTIME: BERTH(FIRST,TYPE)=BERTH(FIRST,TYPE)+XSTIME
  450 IF NN>FDAYS THEN SUMIT(TYPE)=SUMIT(TYPE)+IDLET:CQ(QL,TYPE)= CQ(QL,TYPE)+1
  460 PRINT BERTH(FIRST,TYPE);"  ";
  470 @%=&00020005:PRINT MINDELAY,TSERVICE,WAITIME,IDLET
  490 IF NN<=FDAYS GOTO 530
  500 SUM(TYPE)=SUM(TYPE)+WAITIME :NO(TYPE)=NO(TYPE)+1 : SUMSERV(TYPE)=SUMSERV(T
YPE)+TSERVICE:WT=INT(WAITIME/12):IF WT>50 THEN WT=50
  510 IT=INT(IDLET/12):IF IT>100 THEN IT=100
  520 C(WT,TYPE)=C(WT,TYPE)+1:CI(IT,TYPE)=CI(IT,TYPE)+1
  530 TCONST=TCONST(TYPE)
  540 IF NN=FDAYS THEN FDAYTIME=STIME
  550 PROCINTERV
  560 STIME(TYPE)=STIME(TYPE)+TINTERV
  570 IF NN=NOARRIVS-10 THEN VDU2
  580 NN=NN+1:IF NN<=NOARRIVS GOTO220
  590PRINT' "FIRST ";FDAYS;" ARRIVALS IGNORED."
  600 @%=&0002020B :TIMTOT=TPRINT-FDAYTIME
  610 PRINT "          TYPE   AV.WT.     NO.ARRIV.   TOT.IDLETIME %IDLE TIME AV SE
RVICE  MAXQ"
  620 FOR T=1 TO NT:PRINTT,SUM(T)/NO(T),NO(T),SUMIT(T),SUMIT(T)/TIMTOT*100,SUMSE
RV(T)/NO(T),MAXQL(T)
  630 NEXT T
  640 @%=&00000004
  645 FOR T=1 TO NT :PRINT '"TYPE=";T;" QUEUE LENGTHS"
  647 FOR IQ=0 TO MAXQL(T) :PRINT IQ,CQ(IQ,T)
  648 NEXT IQ: NEXT T
  650 FOR T=1 TO NT :PRINT'"TYPE=";T ;" WAITING TIMES"
  660 FOR IW=0 TO 100
  670 IF C(IW,T)<>0 PRINTIW*12;"-";IW*12+11.99,C(IW,T);"      ";:K=K+1:IF K MO
D 3=0 PRINT
  680 NEXT IW
  690 NEXT T
  700 FOR T=1 TO NT :PRINT'"TYPE=";T; " IDLE TIMES"
  710 K=0:FOR IW=0 TO 200
  720 IF CI(IW,T)<>0 PRINT IW*12;"-";IW*12+11.99,CI(IW,T);"      ";:K=K+1:IF K M
OD 3=0 THENPRINT
  730 NEXT:NEXT  :PRINT
  740 @%=10:VDU3:STOP
  750 DEF PROCINTERV
  760 R=RND(1)
  770 TINTERV=-TCONST*LN(1-R)
  780 ENDPROC
  790 DEF PROCMINDELAY
  810   REM***CHECK ALL BERTHS OF THIS TYPE.
  820 FOR N=1 TO NOBERTH
  840 DELAY=BERTH(N,TYPE)-STIME
  850 IF DELAY<0 THEN MINDELAY=0 :FIRST=N :IDLET=-DELAY:GOTO0870
  860 IF DELAY<MINDELAY THEN MINDELAY=DELAY:FIRST=N
  870 NEXT N
  900 ENDPROC
  940 DEF PROCNORMAL
  950 SUMN=0:FOR I=1 TO 12:R=RND(1)
  960 SUMN=SUMN+R:NEXT I
  970 TSERVICE=STD(TYPE)*(SUMN-6.0)+TSERV(TYPE)
  980 ENDPROC
  990 DEF PROCQSIZE
 1000 START=START(TYPE):FA=FA(TYPE):QUEUE=QUEUE(TYPE)
 1010 Q(FA,TYPE)=ENTERB
 1020 QEND=FA
 1040 IF TPRINT<Q(START,TYPE) GOTO 1070
 1050 IF QUEUE AND START<QEND THEN START=START+1 :GOTO 1040
 1055 IF QUEUE AND START>=QEND THEN START=0 :  FA=0:QL=0:GOTO 1160
 1060 START=START+1
```

```
... IF START>ARRAYSZE THEN START=0:QUEUE=TRUE
1064 GOTO 1040
1070 IF QUEUE THEN QL=QEND-START+1 ELSE QL=ARRAYSZE-START+QEND+2
1080 FA=FA+1
1090 IF FA>ARRAYSZE THEN FA=0:QUEUE=FALSE
1110 IF QUEUE=FALSE AND FA>START THEN PRINT"Q TOO LONG";" START="START;" FA=";F
A ;" QL=";QL
1160 START(TYPE)=START:FA(TYPE)=FA:QUEUE(TYPE)=QUEUE
1170 IF NN>FDAYS AND QL>MAXQL(TYPE) THEN MAXQL(TYPE)=QL
1180 ENDPROC
1190 DATA 1919,42,175,40
1200 DATA 2037,16,54,9
1490 DEF  PROCDELAY(LSTIME)
1500 PROCXSTIME(0,6,HOURS):PROCXSTIME(18,30,HOURS)
1510 D=DAYS-NEWDAYS :IF D=0 GOTO 1560
1520 TIDE1=(TIDE1+D) MOD 24
1530 TIDE2=(TIDE1+6) MOD 24
1540 TIDE3=(TIDE1+12) MOD 24
1550 TIDE4=(TIDE1+18) MOD 24
1560 NEWDAYS=DAYS
1570 IF TIDE2<TIDE1 THEN PROCXSTIME(0,TIDE2,HOURS): PROCXSTIME(TIDE1,TIDE2+24,H
OURS) ELSE PROCXSTIME(TIDE1,TIDE2,HOURS)
1580 IF TIDE4<TIDE3 THEN PROCXSTIME(0,TIDE4,HOURS):PROCXSTIME(TIDE3,TIDE4+24,HO
URS) ELSE PROCXSTIME(TIDE3,TIDE4,HOURS)
1590 IF XST<>0 GOTO 1500
1600 ENDPROC
1610  DEF PROCXSTIME(T1,T2,H)
1620 XST=0
1630 IF H>=T1 AND H<T2 THEN XST=T2-H :XSTIME=XSTIME+XST :HOURS=(LSTIME+XSTIME)
MOD 24
1640 ENDPROC
>RUN
   1 728    1    5    1   37   1217473.   17511.17511.17704.    33.      193.   38.   0.
   2 728    1    5    2   15    617473.   17490.17490.17559.    12.       70.   17.   0.
   2 728    1    5    2    8    717473.   17490.17490.17560.    12.       70.   17.   0.
   1 728    5    1    1    4   1317477.   17526.17526.17743.    48.      216.   47.   0.
   2 728    9    6    2    6    617481.   17502.17502.17550.    15.       48.   21.   0.
   2 728   11    4    2    1    717483.   17503.17503.17551.    16.       48.   20.   0.
   2 728   13    2    2    9    617485.   17503.17503.17574.    16.       71.   18.   0.
   2 728   15    0    2   14    617487.   17509.17509.17575.    22.       66.   22.   0.
   2 728   15    0    2    2    717487.   17510.17510.17574.    23.       65.   23.   0.
   2 728   17    0    2   13    817489.   17526.17526.17599.    37.       73.   37.   0.

FIRST 1956. ARRIVALS IGNORED.
       TYPE    A.W.T.        NO.ARRIV.    TOT.IDLETIME %IDLE TIME AV SERVICE   MAXQ
       1.00      24.57       1871.00     23204.04       270.07      180.22      35.00
       2.00      13.24       2085.00     13710.14       159.57       59.62      18.00

TYPE=1 QUEUE LENGTHS
   0 164
   1 157
   2 134
   3 1 1
   4 1 5
   5 125
   6 117
   7  86
   8  59
   9  48
  10  53
  11  45
  12  29
  13  36
  14  27
  15  1
  1 .
```

```
17  15
18  20
19  27
20  24
21  16
22  10
23  10
24   7
25  10
26   9
27   9
28   7
29   2
30   2
31   2
32   3
33   3
34   2
35   2

TYPE=2 QUEUE LENGTHS
   0 216
   1 301
   2 334
   3 289
   4 235
   5 184
   6 146
   7  97
   8  72
   9  55
  10  42
  11  38
  12  29
  13  20
  14  13
  15   8
  16   4
  17   1
  18   1

TYPE=1 WAITING TIMES
   0-11.99    847        12-23.99 382           24-35.99 181
  36-47.99    150        48-59.99  93           60-71.99  60
  72-83.99     53        84-95.99  37           96-107.99        19
 108-119.99    36       120-131.99       11        132-143.99        2

TYPE=2 WAITING TIMES
   0-11.99   1166        12-23.99 584           24-35.99 212
  36-47.99     80        48-59.99  34           60-71.99   9

TYPE=1 IDLE TIMES
   0-11.99   1390        12-23.99 274           24-35.99  38
  36-47.99     51        48-59.99  14           60-71.99  21
  72-83.99     10        84-95.99  21           96-107.99        8
 108-119.99     9       120-131.99       6         132-143.99        4
 144-155.99     6       156-167.99       5         168-179.99        2
 180-191.99     1       192-203.99       1         204-215.99        3
 216-227.99     2       240-251.99       2         252-263.99        1
 348-359.99     1       360-371.99       1
TYPE=2 IDLE TIMES
   0-11.99   1696        12-23.99 243           24-35.99  55
  36-47.99     29        48-59.99  19           60-71.99  13
  72-83.99      9        84-95.99   6           96-107.99        2
 108-119.99     2       120-131.99       2         132-143.99        2
 144-155.99     1       156-167.99       2         180-191.99        1
```

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240-251.99    1     288-299.99     1          312-323.99          1

>L.
    5 VDU 3
   10 R=RND(-1)
   20 ARRAYSZE=300:TIDE1=0: NEWDAYS=-1
   30 DIM SUMSERV(2),NUMB(2),STD(2),C(100,2),CI(200,2),B(ARRAYSZE,2)
   40 DIM START(2),FA(2),QUEUE(2),MAXQL(2),CQ(300,2)
   50 DIM AVLOAD(2),AVUNLOAD(2),STIME(2),TCONST(2),NOBERTHS(2),BERTH(45,2)
   60 DIM TSERV(2),SUM(2),NO(2),SUMIT(2)
   70 @%=&01000004
   80 PRINT" TYP"," DAY"," HR"," TDE", " BTH"," BTH";" Q ";
   90 @%=&01000007
  100 PRINT  " ARRIV","ENTER","LEFT","LEAVE","DELAY","SERV","WAIT","IDLE"
  110 NOARRIVS=7912
  120 FDAYS=3956:NT=2:NN=1
  130 FOR T=1 TO NT:READ NOSHIPS:TCONST(T)=365*24/NOSHIPS
  140READ NOBERTHS(T),TSERV(T),STD(T):NEXTT
  150    REM***CALC.TIMEINTERVAL CONSTANT FOR EACH SHIP
  160 FOR T=1 TO NT:TCONST=TCONST(T):PROCINTERV
  170    REM***CALC TIME OF FIRST SHIP OF EACH TYPE.
  180 MAXQL(T)=0:QUEUE(T)=TRUE:START(T)=0: FA(T)=0
  190 STIME(T)=TINTERV:NEXT
  200   REM***FIND EARLIEST SHIP.
  210 GOTO220:FOR T=1 TO 3:STIME(T)=10^6:NO(T)=1:NUMB(T)=1 :NEXTT
  220 XSTIME=0:IDLET=0: STIME=10^6:FOR T=1 TO NT
  230IF STIME(T)<STIME THENSTIME=INT(STIME(T)):TYPE=T
  240 NEXT T:TPRINT=STIME
  250 HOURS=STIME MOD 24: DAYS=STIME DIV 24 :HRS=HOURS
  260 PROCDELAY(STIME)
  290 STIME=STIME+XSTIME
  300   REM*** CALC TIME TO LOAD & UNLOAD.
  310 PROCNORMAL
  320 NOBERTH=NOBERTHS(TYPE):MINDELAY=100000
  330 @%=&00000004
  340 PRINT  TYPE,DAYS,HRS,XSTIME;
  350 PROCMINDELAY
  380 ENTERB=STIME+MINDELAY:PROCQSIZE :PRINT TYPE,FIRST,QL;
  390 @%=&00020006:PRINT TPRINT,ENTERB,BERTH(FIRST,TYPE);
  400 WAITIME=MINDELAY+XSTIME
  410
  420 BERTH(FIRST,TYPE)=STIME+MINDELAY+TSERVICE :HOURS=BERTH(FIRST,TYPE) MOD 24:
 LTIME=BERTH(FIRST,TYPE)
  425 HR=HOURS
  430 XSTIME=0: PROCDELAY(LTIME)
  440 TSERVICE=TSERVICE+XSTIME: BERTH(FIRST,TYPE)=BERTH(FIRST,TYPE)+XSTIME
  450 IF NN>FDAYS THEN SUMIT(TYPE)=SUMIT(TYPE)+IDLET:CQ(QL,TYPE)= CQ(QL,TYPE)+1
  460 PRINT BERTH(FIRST,TYPE);"  ";
  470 @%=&00020005:PRINT MINDELAY,TSERVICE,WAITIME,IDLET
  490 IF NN<=FDAYS GOTO 530
  500 SUM(TYPE)=SUM(TYPE)+WAITIME :NO(TYPE)=NO(TYPE)+1 : SUMSERV(TYPE)=SUMSERV(T
YPE)+TSERVICE:WT=INT(WAITIME/12):IF WT>50 THEN WT=50
  510 IT=INT(IDLET/12):IF IT>100 THEN IT=100
  520 C(WT,TYPE)=C(WT,TYPE)+1:CI(IT,TYPE)=CI(IT,TYPE)+1
  530 TCONST=TCONST(TYPE)
  540 IF NN=FDAYS THEN FDAYTIME=STIME
  550 PROCINTERV
  560 STIME(TYPE)=STIME(TYPE)+TINTERV
  570 IF NN=NOARRIVS-10 THEN VDU2
  580 NN=NN+1:IF NN<=NOARRIVS GOTO220
  590PRINT' "FIRST ";FDAYS;" ARRIVALS IGNORED."
  600 @%=&0002020B :TIMTOT=TPRINT-FDAYTIME
  610 PRINT "          TYPE   AV.WT.    NO.ARRIV.   TOT.IDLETIME %IDLE TIME AV SE
RVICE   MAXQ"
  620 FOR T=1 TO NT:PRINTT,SUM(T)/NO(T),NO(T),SUMIT(T),SUMIT(T)/TIMTOT*100,SUMSE
RV(T)/NO(T),MAXQL(T)
```

```
630 NEXT I
640 @%=&00000004
645 FOR T=1 TO NT :PRINT '"TYPE=";T;" QUEUE LENGTHS"
647 FOR IQ=0 TO MAXQL(T) :PRINT IQ,CQ(IQ,T)
648 NEXT IQ: NEXT T
650 FOR T=1 TO NT :PRINT'"TYPE=";T ;" WAITING TIMES"
660 FOR IW=0 TO 100
670 IF C(IW,T)<>0 PRINTIW*12;"-";IW*12+11.99,C(IW,T);"        ";:K=K+1:IF K MOD
3=0 PRINT
680 NEXT IW
690 NEXT T
700 FOR T=1 TO NT :PRINT'"TYPE=";T; " IDLE TIMES"
710 K=0:FOR IW=0 TO 200
720 IF CI(IW,T)<>0 PRINT IW*12;"-";IW*12+11.99,CI(IW,T);"        ";:K=K+1:IF K M
OD 3=0 THENPRINT
730 NEXT:NEXT  :PRINT
740 @%=10:VDU3:STOP
750 DEF PROCINTERV
760 R=RND(1)
770 TINTERV=-TCONST*LN(1-R)
780 ENDPROC
790 DEF PROCMINDELAY
810   REM***CHECK ALL BERTHS OF THIS TYPE.
820 FOR N=1 TO NOBERTH
840 DELAY=BERTH(N,TYPE)-STIME
850 IF DELAY<0 THEN MINDELAY=0 :FIRST=N :IDLET=-DELAY:GOTO870
860 IF DELAY<MINDELAY THEN MINDELAY=DELAY:FIRST=N
870 NEXT N
900 ENDPROC
940 DEF PROCNORMAL
950 SUMN=0:FOR I=1 TO 12:R=RND(1)
960 SUMN=SUMN+R:NEXT I
970 TSERVICE=STD(TYPE)*(SUMN-6.0)+TSERV(TYPE)
980 ENDPROC
990 DEF PROCQSIZE
1000 START=START(TYPE):FA=FA(TYPE):QUEUE=QUEUE(TYPE)
1010 Q(FA,TYPE)=ENTERB
1020 QEND=FA
1040 IF TPRINT<Q(START,TYPE) GOTO 1070
1050 IF QUEUE AND START<QEND THEN START=START+1 :GOTO 1040
1055 IF QUEUE AND START>=QEND THEN START=0 :  FA=0:QL=0:GOTO 1160
1060 START=START+1
1062 IF START>ARRAYSZE THEN START=0:QUEUE=TRUE
1064 GOTO 1040
1070 IF QUEUE THEN QL=QEND-START+1 ELSE QL=ARRAYSZE-START+QEND+2
1080 FA=FA+1
1090 IF FA>ARRAYSZE THEN FA=0:QUEUE=FALSE
1110 IF QUEUE=FALSE AND FA>START THEN PRINT"Q TOO LONG";" START=";START;" FA=";F
A ;" QL=";QL
1150 START(TYPE)=START:FA(TYPE)=FA:QUEUE(TYPE)=QUEUE
1170 IF DN>FDAYS AND QL>MAXQL(TYPE) THEN MAXQL(TYPE)=QL
1180 ENDPROC
1190 DATA 1919,43,175,40
1200 DATA 2037,17,54,9
1490 DEF  PROCDELAY(LSTIME)
1500 PROCXSTIME(0,6,HOURS):PROCXSTIME(18,30,HOURS)
1510 D=DAYS-NEWDAYS :IF D=0 GOTO 1560
1520 TIDE1=(TIDE1+D) MOD 24
1530 TIDE2=(TIDE1+6) MOD 24
1540 TIDE3=(TIDE1+12) MOD 24
1550 TIDE4=(TIDE1+18) MOD 24
1560 NEWDAYS=DAYS
1570 IF TIDE2<TIDE1 THEN PROCXSTIME(0,TIDE2,HOURS): PROCXSTIME(TIDE1,TIDE2+24,H
OURS)ELSE PROCXSTIME(TIDE1,TIDE2,HOURS)
1580 IF TIDE4<TIDE3 THEN PROCXSTIME(0,TIDE4,HOURS):PROCXSTIME(TIDE3,TIDE4+24,HO
URS) ELSE PROCXSTIME(TIDE3,TIDE4,HOURS)
```

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[illegible]
 1600 ENDPROC
 1610  DEF PROCXSTIME(T1,T2,H)
 1620 XST=0
 1630 IF H>=T1 AND H<T2 THEN XST=T2-H :XSTIME=XSTIME+XST :HOURS=(LSTIME+XSTIME)
MOD 24
 1640 ENDPROC
>RUN
   1 728   1   5   1  23  1117473.  17508.17508.17696.   30.   188.  35.   0.
   2 728   1   5   2  17   517473.  17485.17485.17559.    7.    75.  12.   0.
   2 728   1   5   2   4   617473.  17485.17485.17551.    7. [illegible]  12.   0.
   1 728   5   1   1  25  1217477.  17508.17508.17719.   30. [illegible]  31.   0.
   2 728   9   6   2  12   417481.  17490.17490.17550.    3. [illegible]   9.   0.
   2 728  11   4   2  11   517483.  17502.17502.17550.   15. [illegible]  19.   0.
   2 728  13   2   2   2   417485.  17503.17503.17575.   16.    72.  18.   0.
   2 728  15   0   2   6   417487.  17503.17503.17575.   16.    72.  16.   0.
   2 728  15   0   2  16   517487.  17509.17509.17562.   22.    53.  22.   0.
   2 728  17   0   2   3   617489.  17510.17510.17574.   21.    65.  21.   0.

FIRST 3956. ARRIVALS IGNORED.
        TYPE    AV.WT.       NO.ARRIV.   TOT.IDLETIME %IDLE TIME AV SERVICE  MAXQ
        1.00     18.75       1871.00     33673.00      391.91     180.28      29.00
        2.00      9.71       2085.00     22334.87      259.95      59.60      15.00

TYPE=1 QUEUE LENGTHS
   0 228
   1 300
   2 253
   3 222
   4 173
   5 141
   6  90
   7  49
   8  45
   9  45
  10  47
  11  40
  12  45
  13  29
  14  31
  15  30
  16  20
  17  11
  18  10
  19  14
  20  10
  21  12
  22   5
  23   4
  24   3
  25   4
  26   4
  27   2
  28   3
  29   1

TYPE=2 QUEUE LENGTHS
   0 294
   1 386
   2 363
   3 299
   4 240
   5 163
   6 116
   7  73
   8  50
```

[illegible]	[illegible]
10	27
11	15
12	8
13	4
14	3
15	1

TYPE=1 WAITING TIMES

0-11.99	1009	12-23.99	367	24-35.99	160
36-47.99	111	48-59.99	95	60-71.99	50
72-83.99	31	84-95.99	40	96-107.99	7
108-119.99	1				

TYPE=2 WAITING TIMES

0-11.99	1417	12-23.99	508		
24-35.99	121	36-47.99	36	48-59.99	3

TYPE=1 IDLE TIMES

0-11.99	1264	12-23.99	319	24-35.99	46
36-47.99	64	48-59.99	19	60-71.99	42
72-83.99	14	84-95.99	23	96-107.99	9
108-119.99	12	120-131.99	4	132-143.99	12
144-155.99	5	156-167.99	5	168-179.99	3
180-191.99	1	192-203.99	8	204-215.99	2
216-227.99	1	228-239.99	3	240-251.99	3
252-263.99	1	264-275.99	1	276-287.99	1
288-299.99	1	300-311.99	2	348-359.99	1
360-371.99	2	372-383.99	2	408-419.99	1

TYPE=2 IDLE TIMES

0-11.99	1486	12-23.99	360	24-35.99	84
36-47.99	38	48-59.99	29	60-71.99	29
72-83.99	16	84-95.99	12	96-107.99	8
108-119.99	5	120-131.99	1	132-143.99	5
144-155.99	2	156-167.99	4	180-191.99	1
204-215.99	1	240-251.99	1	288-299.99	1
312-323.99	1	348-359.99	1		